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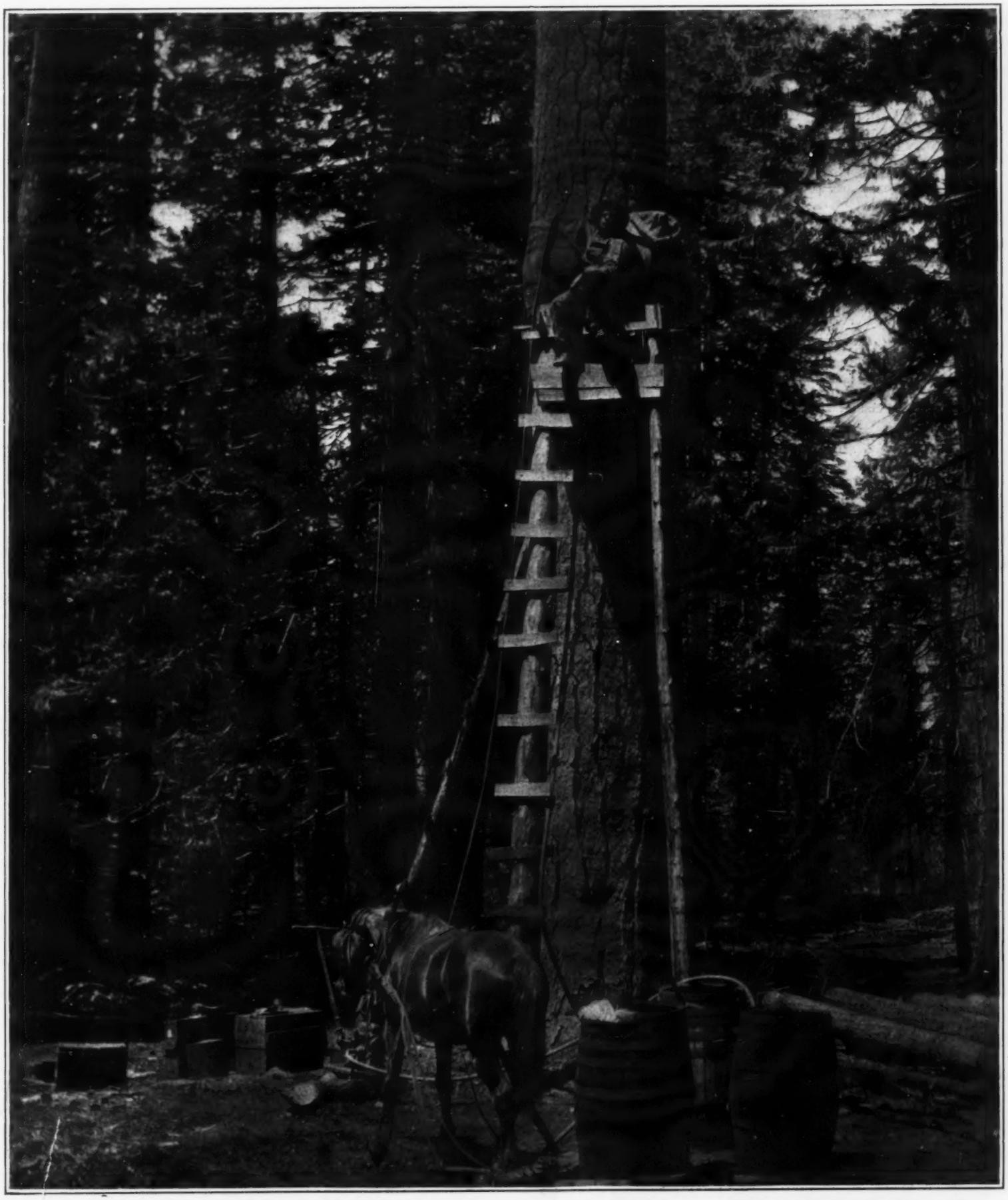


The Boucherie process for preserving timber. View showing elevated tank, pump for elevating liquid, and poles being treated.

THE DEVELOPMENT AND STATUS OF THE WOOD PRESERVING INDUSTRY.—[See page 24.]

Radiation Pressure

Its Nature and Significance

By Prof. Wilson C. Morris, State Normal School, Warrensburg, Mo.

ANY one who has read some of the recent works of the great scientist, Svante Arrhenius, must be impressed by the uses he makes of radiation pressure in explaining many troublesome problems that confront the student of cosmical physics. Following in the steps of Kepler he attributes the repulsion of comets' tails to this agency. Meteorites, although constantly being caught up by larger bodies, have not diminished in number as they are constantly arising from the accrescence of small particles which radiation pressure has driven from the sun. He argues this mode of origin from their structure.

If there is disintegration of radioactive matter in the sun, alpha and beta particles will be shot off. The initial velocity of the alpha particles is about one fifteenth that of light, while the velocity of the beta particles is nearly the same as that of light. An initial velocity of the order of 400 miles per second is sufficient to overcome the sun's gravitational attraction. The alpha and beta particles in traversing the sun's atmosphere lose the greater part of their initial velocities so that their speeds may be of the order of those of particles moving under the sun's radiation pressure alone. When these particles reach the outer and relatively cooler portion of the sun's atmosphere they increase in size (become "loaded" with particles of dust or accretions of vapor). Some may attain such a size that the sun's gravitational attraction more than balances the initial impulse. Owing to their much higher initial velocity and their much smaller mass, the number of beta particles falling back will be much smaller than the number of alpha ones; hence, there will be a resultant flow of negative electricity from the sun. Given these negatively charged particles projected from the sun by the explosive force arising from atomic disintegration and by radiation pressure, Arrhenius interprets the coronal streamers in terms of these. According to his interpretation the polar lights, which are electric discharges in the upper strata of the earth's atmosphere, are due to this electrically charged dust which the sun sends us. By this same agency (radiation pressure) Arrhenius finds a means by which the available energy of the universe is regenerated, although the opinion is held, or at least was held before the days of radioactivity, that the non-available energy tends to a maximum. Even the distribution of life throughout the universe is attributed by him to this wonderful force (light pressure).

Those having an interest in these problems will do well to read two of the rather recent works by Arrhenius, "Worlds in the Making" and "The Life of the Universe." In writing this paper it is no part of my task to discuss the aforesaid works; but rather, to present in a form that can be comprehended by those who have not had much training in physics, some information on this agency so extensively relied upon by the great Swedish thinker in his books on world-building.

The history of radiation pressure involves a history of the two rival theories of light. Shortly after the time of Roemer's determination of the velocity of light from the observation of the eclipses of one of Jupiter's moons, Huygens prepared a manuscript on the wave theory of light and communicated it to some physicists of the French Academy. It was later (1690) published at Leyden. The problem before Huygens was whether light is due to the vibratory motion of a space-filling medium as supposed by Hooke, the man who foreshadowed so much now known in physics; or whether it was due to a stream of particles issuing from a luminous body, as was generally believed from the time of certain Greek philosophers. Neither the idea of an ether nor the undulatory motion of it as the origin of light is original with Huygens, as is generally thought, but such an impulse did his famous "Traite de la Lumière" give this theory, that we are justified in referring to the wave theory as Huygen's theory. This theory was rejected by Newton because of its incompetence to account for rectilinear propagation, and the phenomenon now called polarization, which was discovered by Huygens himself. Had he been able to explain polarization, he would have dealt the emission theory a severe blow. He failed to explain polarization because, being familiar with sound-waves which are longitudinal, he assumed that light-waves are of the same type.

Because of the unanswered objections, Newton favored the corpuscular theory; but even the genius of Newton could not free the theory from very serious objections—so serious that it had to be finally abandoned. Be it said to the credit of Newton that his objections against the wave theory as it was understood by his contemporaries are valid. His objections lose their validity when we take up the wave theory after it has passed through the hands of Young and Fresnel.

Until the time then of Young and Fresnel, Huygen's theory was kept in the background because of the great authority enjoyed by Newton; however, it had some advocates. One of the best known among these during the "dark period" was the mathematician Euler. Not only did he advocate the wave theory, but in 1746 he expressed the opinion that waves of light exert a pressure upon bodies on which they impinge. These are his words: "Just as a vehement sound excites not only a vibratory motion in the particles of the air, but there is also observed a real movement of the small particles of dust which are suspended therein, it is not to be doubted but that the vibratory motion set up by light causes a similar effect." That this suggestion was worthy of more careful consideration than it received will be seen by studying the work of Maxwell, Bartoli, Lebedew and Nichols and Hull.

If it be true that light is a stream of rapidly moving corpuscles, as was so strongly advocated, then that there should be a push exerted against a body by these impinging corpuscles is evident; but that pressure should be a characteristic of an undulatory theory, as was suggested by Euler, was given little thought until the publication of Maxwell's electromagnetic theory of light (1873), and of Bartoli's work on the application of thermodynamics to radiation (1876), which was several years after the corpuscular theory had met its death.

There were numerous efforts made during the eighteenth century to detect this supposed pressure; but all were made with a view to testing the validity of the particle theory; for the adherents of the emission theory believed that they had a means of decisive confirmation if they could show that a beam of light possesses momentum, a characteristic of a moving particle. The general mode of experimentation consisted in directing powerful beams of light against delicately-suspended disks. In 1708 Homberg performed such an experiment and fancied he detected the pressure effects; but Du Fay, who repeated his experiment some years later, failed to confirm his results. Mitchell, well known because he constructed the apparatus to which Cavendish fell heir for his now celebrated experiment on the determination of the gravitational constant, took up the work. By means of a mirror he concentrated the sun's rays upon a thin sensitively-suspended copper plate and observed the deflection. He was not satisfied with his results, as he was not sure that he had altogether excluded convection currents of air. Bennett a few years later performed a very similar experiment, but could perceive no motion distinct from heat effects. Indeed, both he and Young regarded the failure of these experiments in detecting light pressure as an argument in favor of the wave theory.

It is fortunate that, owing to experimental difficulties not overcome until recently (1900), these early experimenters failed; for success on their part would have meant a hard blow, may be a death blow, to the wave theory. I will leave it to the reader to imagine what would have been our present status of optics, had radiation pressure been detected before the days of Young, Fresnel and Maxwell. Let me put the question as Sir J. J. Thomson put it in one of his class lectures: "The task of Young and Fresnel was difficult, but what would it have been had it not been performed before the discovery of radiation pressure, the ionization by ultra-violet rays, and the emission of alpha and beta particles from radium, the beta particles having a velocity approximately that of light?" I might say in passing that radiation pressure is not the only phenomenon to which the corpuscular theory lends an easier explanation than the wave theory. Ionization by ultra-violet rays is much more easily explained by the emission theory. Indeed, an explanation of the photo-electric phenomena seems to demand some modification of our former conception of the wave-front. According to modern views of light, the energy is not spread uniformly over an ever-increasing wave-front, but is concentrated at certain points upon the wave-fronts. Hence, just as matter is discrete, so, if we follow Planck, Einstein and others, we are led to view energy of light waves as discrete or to give to light waves something resembling structure. Sir J. J. Thomson in one of his class lectures puts it thus: "One thing is probably true, that the energy in radiation is not uniformly distributed, but we may regard it as representing bright spots on a dark background." Prof. Thomson in his class lectures on "Ether" was inclined to attribute a *fibrous structure* to it; and hence light is only a transverse disturbance along these fibers (lines of force). For a good discussion of the modern views of radiation, the reader is referred to Prof. Millikan's address before the American Association for the Advancement of Science (see *Science*, January 24th, 1913).

One of the most important contributions to physics during the nineteenth century, so famous for its advances in science, was the development of the electromagnetic theory of light by the great Scotch physicist, Maxwell. It is needless to say that a theory as comprehensive as this cannot be put into a few words, for the great merit of Maxwell's work lies largely in the methods of mathematical analysis developed by him. According to Maxwell there exists a space-filling medium, not composed of gravitative or ordinary matter, possessing qualities which permit the establishment therein of two physical states (electric displacement and magnetic flux). When these states are established they spread out with a velocity which is the same as that of light; hence, from the equality of the speeds of these electromagnetic disturbances (waves) and light-waves, he concluded that light is an electromagnetic disturbance propagated through the ether. This theory was not generally accepted until after the epoch-making experiments of Hertz.

The electromagnetic field is considered as the seat of two kinds of energy (electric and magnetic), and this energy flows in a direction perpendicular both to the electric force and to the magnetic force; or picturing the field as made up of Faraday tubes or lines of force, these tubes, moving at right angles to their own direction, give a momentum at each point in the field which is in the direction of the motion of the tube and at right angles both to the electric force and to the magnetic force. For the magnitude of this momentum the reader is referred to J. J. Thomson's "Electricity and Magnetism," page 518. Hence, if light is an electromagnetic disturbance, light-waves are accompanied by a stream of momentum in the direction of propagation; and since force (pressure in our case) is the time-rate of charge of momentum, bodies upon which waves impinge will experience a pressure as truly as from impinging particles. The following quotation from Whittaker's "Theories of the Ether and Electricity" may help in seeing the reason for the existence of light pressure on the electromagnetic theory. "Suppose light falls on a metallic reflecting surface at perpendicular incidence. The light may be regarded as constituted of a rapidly-alternating magnetic field; and this must induce electric currents in the surface layers of the metal. But a metal carrying currents in a magnetic field is acted on by a ponderomotive force, which is at right angles to both the magnetic force and the direction of the current, and is, therefore, in the present case, normal to the reflecting surface; this ponderomotive force is the light pressure."

Not only did Maxwell predict light pressure, but he calculated the amount per unit area due to sunlight. Nearly thirty years later, when it was first measured by the Russian physicist Lebedew, and later by the American physicists Nichols and Hull, both his prediction and calculation were substantiated. The observed and calculated values agree as closely as could be expected when we consider the delicacy of manipulation required to even detect this small pressure, much more to measure it, since under ordinary conditions in the methods used it is screened by both the radiometric (heat) effect and by convection currents of air. The one characteristic of light pressure is its minuteness, and because of this it remained undetected until delicacy in manipulating apparatus had reached its present high state of perfection.

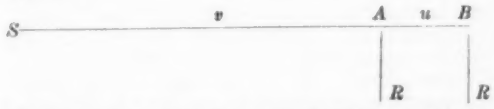
A few years after it had been shown by Maxwell that if light is interpreted as an electromagnetic disturbance it must exert a pressure when it falls upon reflecting and absorbing surfaces, Bartoli pointed out the necessary existence of a radiation pressure by showing that the second law of thermodynamics is violated when radiant energy is transported from a cold body to a hot one by means of a moving mirror unless pressure is exerted on the mirror by the radiation. Boltzmann, making use of Bartoli's suggestion, was enabled to arrive at Stefan's experimental law (the total

radiation from a hot body is proportional to the fourth power of the absolute temperature). Pressure, then, is a general property of all waves impinging upon reflecting and absorbing surfaces; and hence applies to sound-waves as well as electromagnetic ones. Altberg, working in the laboratory of Lebedew, detected and measured it for sound. For his method see Barton's "Sound," page 601.

Larmor has given a simple indirect method of proving the existence of radiation pressure (see Encyclopaedia Britannica on "Radiation"). Let radiation fall normally on a mirror which moves normally in a direction opposite to that of wave propagation, so as to meet the incident waves. The reflected waves will be of shorter length but of the same amplitude, and as the energy in a given length is inversely proportional to the square of the wave length, the reflected waves will contain more energy per unit length or will radiate more energy per unit time than the incident waves, as the incident and reflected pulses travel with the same speed. This excess of energy must come from the work done by the moving mirror; but to do work we must overcome resistance, and the resistance overcome in this case must be the pressure of the incident beam.

According to Maxwell if an electromagnetic wave falls normally upon a plane surface (all surfaces considered in this paper are assumed to be either perfect reflectors or perfect absorbers), the pressure exerted per unit area is numerically equal to the energy contained in a unit volume of the vibrating system. If we place a light inside a hollow sphere where the waves are incident in all directions, then the pressure is only one third the density of the energy of radiation. Those who have had an elementary course in wave motion will find a proof of this statement in Barton's "Sound," which is based on Larmor's article previously referred to.

Let us calculate the pressure of a beam incident normally on a *perfectly reflecting*, and a *perfectly absorbing* surface. Those familiar with Döppler's principle which is given in high school physics will be able to follow the proof.



S is a source of light; R is a perfect reflector. B is the initial position of the reflector, A is its position one second later. SA is the space over which the wave moves per second. Let v equal the speed of the wave motion, u equal the speed of the reflector which is approaching the source. Then during a second the reflector receives the radiation contained in a length SB $(v+u)$; but the reflected pulses traveling in the same direction as the reflector will be crowded into a length $(v-u)$; hence if l_1 is wave length of the incident beam and l_2 of the reflected beam, $l_1/l_2 = \dfrac{v+u}{v-u}$ (1)

Since from the condition of the case the disturbance does not penetrate the reflector but is annulled at the surface, it follows that the amplitudes of the incident and reflected pulses are equal in magnitude. The energy per unit length, or for any given length, in wave-trains of the same amplitude is inversely proportional to the square of the wave-length.

Let E_1 be the energy per unit volume in the incident waves.

Let E_2 be the energy per unit volume in the reflected waves.

From what has been said $E_1/E_2 = l_2^2/l_1^2$ (2)

From equations (1) and (2) $E_2 = E_1\left(\dfrac{v+u}{v-u}\right)^2$ (3)

The energy of the reflected beam $= E_2(v-u)$.

The energy of the incident beam $= E_1(v+u)$.

The increase in energy per second $= E_2(v-u) - E_1(v+u)$ (4)

From equations 3 and 4 the [increase in energy per second $= E_1\left[\dfrac{(v+u)}{(v-u)}\right] 2u$.

This increase is due to the work done in moving the reflector forward against the beam. If P is the pressure per unit area, the work done per second $= Pu$; but this is equal to the increase in energy per second $\therefore Pu = 2E_1u\left(\dfrac{v+u}{v-u}\right)$ or $P = 2E_1\left(\dfrac{v+u}{v-u}\right)$ (6)

The energy per unit in the incident and reflected waves $= E_1 + E_2 = E_1 + E_1\left(\dfrac{v+u}{v-u}\right)^2$ (see equation 3) $= 2E_1\left[\dfrac{(v^2+u^2)}{(v-u)^2}\right]$ (7)

From equation (6) and (7,) $P = (E_1 + E_2)\left(\dfrac{v^2-u^2}{v^2+u^2}\right) = \left(1 - \dfrac{2u^2}{v^2}\right)(E_1 + E_2)$ (8)

since u is small compared with v.

If the reflector is at rest $u=o$, and since we are dealing with complete reflection $E_1 = E_2$. Call the amount per unit volume E; that is, drop the subscripts since the incident light and reflected light are equal in complete reflection. Therefore, the pressure $= 2E$ [see equation (8)]. If the surface is a perfect absorber $E_2 = o$, and if the absorber is at rest $u=o$; therefore, the pressure $= E$. See equation (8).

We can now calculate the pressure per square centimeter due to sunlight on the earth, assuming that it is a *perfect absorber* (which is not wholly true). Careful determinations have shown that a square centimeter of the earth's surface receives about 2.5 grammes-calories per minute from the sun (see Preston's "Heat," pp. 616-620). This energy is contained in a column 1 square centimeter cross section and $60 \times 3 \times 10^{10}$ centimeters long (the space radiant energy travels per minute).

Hence the number of ergs per centimeter

$$= \frac{2.5 \times 4.19 \times 10^7}{60 \times 3 \times 10^{10}} = 5.8 \times 10^{-5}$$

and hence the pressure per square centimeter $= 5.8 \times 10^{-5}$ dynes, since we have shown the pressure per unit area is numerically equal to the energy per unit volume, for normal incidence and perfect absorbers. When we consider that a dyne is about 1/444,000 of a pound we see how minute this pressure really is. The entire pressure of the sun's radiation on a full-grown man would be of the order of half a milligramme weight.

We are now in position to compare the two light theories using radiation pressure as a criterion, although the comparison is really unnecessary, as work on velocity-determination of light in different media removed the last hope for the emission-theory. On the wave theory we have just proved that the pressure per unit area on a perfect absorber is numerically equal to the energy per unit volume for normal incidence. If M is the mass of particles in the corpuscular theory per unit volume then the mass impinging per second is equal to MV, where V is the velocity of light, and the change of momentum per second $= MV^2$, hence the pressure $= MV^2$. The energy, if the motion is wholly translational, is equal to $\frac{1}{2} MV^2$, where V is the velocity of light. In other words, this hypothesis would lead to the conclusion that the pressure of light was equal to twice the energy per unit volume of the incident beam, when there is complete absorption. This is not in accord with experimental observation. Hence that which was at one time vigorously sought in order to establish beyond doubt the corpuscular theory lends its influence to-day to the wave-theory. It is needless to say that the wave-theory does not make use of this support, as it finds its chief support in the more commonly known and more easily observed interference phenomena.

It is interesting to compare radiation pressure and gravitation, two antagonistic forces. From what we have said of the minuteness of radiation pressure it is needless to say that for large bodies it is trivial as compared with gravitation. If the earth were a perfect absorber the entire pressure of the sun's radiation upon it would be $\dfrac{(6\times10^8)^2 \times 3.14 \times 5.8 \times 10^{-5}}{980 \times 453 \times 2{,}000}$ tons weight. This is about one and one half times the weight of the largest steamship afloat. Note that in getting radiation pressure we use the effective area of the earth $(6\times10^8)^2 \times 3.14$ square centimeters. The gravitational force of the sun on the earth is equal to $\dfrac{27 \times 6 \times 10^{21}}{(213)^2}$ tons weight, because the intensity of the force of gravitation on the sun is 27 times that of the earth, and the earth's mass is 6×10^{21} tons and its distance from the sun is 213 times the solar radius. Hence the sun's radiation pressure on the earth sinks in insignificance when compared with its gravitative pull; but as gravity is proportional to the cube of linear dimension and effective surface is proportional to the square of the linear dimensions, we reach a dimension at which these two antagonistic forces balance each other. Let us find the *linear dimension* of such a particle if it is a *perfect absorber* and has *the density of water*.

Let R = the earth's distance from the sun in centimeters (92,500,000 miles). Then if the pressure on one square centimeter at a distance $R = 5.8 \times 10^{-5}$ dynes, the pressure on the same surface at any distance L centimeters $= 5.8 \times 10^{-5} R^2/L^2$ dynes, since intensity and hence pressure is inversely as the square of the distance. The amount of pressure on a particle of radius r centimeters at a distance $L = 5.8 \times 10^{-5} R^2 \pi r^2 / L^2$ dynes, where πr^2 is the effective area. The sun's pull on this same particle at a distance L centimeters $= 4/3\pi r^3 Mg/L^2$ dynes, where $4/3\pi r^3$ is the mass of the particle, M is the sun's mass $(1.8\times10^{33}$ grammes) and g is the gravitational constant $(6.6\times10^{-8}$ in C.G.S. units). If these two forces *just* balance each other $\pi r^2 \times 5.8 \times 10^{-5} R^2/L^2 = 4/3\pi r^3 Mg/L^2$.

Substituting the values of R, M and g in C.G.S. units, r is found to be equal to 7.3×10^{-6} centimeters. Note that L drops out as each force is inversely proportional to the square of the distance. Hence if they are equal for one distance they are equal for all distances.

As the radius of the particle becomes smaller and smaller the ratio of radiation pressure to gravitation pressure becomes larger and larger; however, it has been shown by Schwarzchild that this does not hold for an indefinite range. There is a critical size at which the ratio of radiation pressure to gravitation is maximum. If the particles become too small radiation does not exert a pressure on them, and hence the gravitational force again predominates. According to Schwarzchild gravitational attraction will prevail when the circumference of the particle is less the three tenths the wave-length of the incident light. Hence, since molecules are very small compared with light waves or even with the shortest ultra-violet waves, the laws as derived will not apply to a gas (a swarm of molecules in which the space separating the particles is large compared with molecular dimension).

We have said little about the experimental side. Experiments requiring such delicacy in construction and such care in manipulation cannot be fully discussed in a short semi-technical paper. After Maxwell had calculated the radiation pressure for sunlight and noticed its minuteness he was led to make the following suggestion, which is really the general method involved in the experimental work. "A much greater energy of radiation might be obtained by means of the concentrated rays of the electric lamp. Such rays falling on a thin metallic disk, delicately suspended in a vacuum, might perhaps produce an observable mechanical effect" (see Maxwell's "Electricity and Magnetism"). This was Lebedew's method. For a short description of Lebedew's work I refer you to Poynting's little volume, "The Pressure of Light." Wood in his "Physical Optics," 1911 edition, devotes two pages to the work of Nichols and Hull. In each of these books the original sources are mentioned.

One of the troublesome things in these experiments is the elimination of, or the correction for, convection currents. Had the above-named experimenters waited a few years they would have been able to improve the vacuum by means of Dewar's method, which is based on the fact that charcoal at the temperature of liquid air boiling at low pressure is able to absorb nearly all the residual gas, and hence the degree of exhaustion is exceedingly high. (See Encyclopaedia Britannica on "Liquid Gases.")

I can't pass by the experimental work on radiation pressure without mentioning the radiometer, a piece of apparatus familiar to high-school boys. It is an outgrowth of Crooke's work in his attempt to detect radiation pressure. It is sometimes called the "light-mill," but there is no justification for this name as the rotation is the result of unequal heating of the light and dark sides of the vanes.

With this elementary knowledge we are now ready to examine some of the problems solved by Arrhenius by making use of this agency; although as stated in the beginning it is not the purpose of this paper to do that. Let us look at just one and that a very famous one, the repulsion of comet's tails. Before we can apply what we have learned we must ask the astrophysicist to give us some information concerning the nature of the comet's tail. If it is gaseous (see Wood's "Physical Optics," page 613) it is not probable that a gas will absorb from sunlight momentum sufficient to account for the motion of the tail. If, on the other hand, we take De Tunzelmann's statement in his book, "A Treatise on Electrical Theories": "Spectroscopic observations show that the tails of comets are composed of solid particles, and not of masses of gas, and indicate that they consist largely of hydrocarbons," then we can account for the repulsion, if the particles are of the proper dimension.

Before bringing this paper to a close I must quote once more from the master, Maxwell,[1] "We discover stars in space by their light and exclusively by this aid, which are so far apart that nothing *material* can ever have traveled from one to the other, and yet the same light tells us that every one of these stars has been built up out of the same atoms that we find on the earth." Yet Maxwell himself predicted, and told how to detect, an agent by which stars communicate with each other by interchanging their material.

Sudden Blanching of the Hair

One reads occasionally in novels and other literature of cases in which a persons hair was turned white within one single night, under some severe mental stress. An alleged historical case of this kind is that of Marie Antoinette. The true cause of the blanching of the hair is a matter of some dispute, says *Prometheus*. Landois, who investigated a case of sudden graying of a man's hair in Greifswald, reported that the inner canal of the hair had become filled with small air bubbles, which imparted to it its white appearance. According to Metchnikow on the other hand the phenomenon is due to the destruction of the hair pigment by the phagocyte cells. Others deny altogether the truth of reports of sudden blanching, or assert that where it has occurred, this may have been due simply to the fact that the person in question was suddenly placed under circumstances compelling the discontinuance of the practice of hair dyeing.

[1] See Glazebrook's book "Maxwell and Modern Physics."

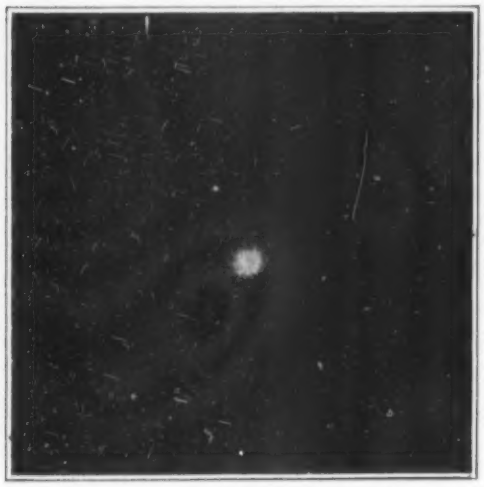


Fig. 8.—The star cluster M13 in Hercules. One stage in the evolution of a solar system.

The Origin of Worlds—II*

The Evolution of Solar Systems Illustrated by Laboratory Experiments

By Prof. Kristian Birkeland

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 1957, July 5th, 1913, Page 12

Fig. 9.—Two luminous spirals proceeding from opposite points of magnetized spherical cathode.

INTERSTELLAR SPACE.

The hypothesis that every star in the course of its evolution projects into space electric corpuscles, by reason of radioactivity, in the extended sense in which that term is here employed, naturally leads to a conception which seems to bear far reaching consequences, when we come to consider the mechanism of the universe. Indeed, it seems plausible to suppose that the greatest amount of matter in the universe is not to be found in stars or in nebulæ, but in interstellar airless space, which may be supposed completely filled with flying corpuscles of every nature—electrons, atoms, molecules or coarser particles, electrified or not, representing all the different chemical elements.

If a mass, such as our solar system, were divided uniformly, in the form of iron atoms for example, in a globe having a radius equal to the distance from the earth to the nearest star (alpha Centauri) there would be only one atom in every eight cubic centimeters of space.

But whether it be for optical reasons or because of the resistance that celestial bodies encounter in their movement, or again because of the absorption in space of the corpuscular rays emitted by the sun, it seems that we may assume in space a density of corpuscles one hundred times greater than that just mentioned, without violating the teachings of past experience.

If, then, we imagine a globe having its center in our solar system and having a radius of five thousand light years, the hundreds of millions of stars of the Milky Way could certainly be inclosed in it, but, nevertheless, it is possible that the airless space in the globe would still contain, in the form of invisible corpuscles, one hundred times more material particles than all the stars together.

The atomic or molecular dust, supposed to exist in space, may be considered up to a certain point as matter in a fourth state of aggregation, almost like the "radiant matter" of Crookes, differing appreciably from gaseous matter in the sense that the molecules have a real living force and almost no degraded energy in the form of heat movement.

Some physicists regard atoms as ether vortices among electric masses. If this idea is accepted, it is easy enough to imagine a combination of an infinite ether-sea with my hypothesis of atoms flying in infinite space—an infinite ether filled everywhere with ether vortices.

Naturally it cannot be supposed that the density of these flying corpuscles is everywhere uniform. It is probable that this density, especially around the sun, is enormously greater, since it is admitted that the sun projects corpuscles of every kind.

It would seem that we have here a plausible explanation for a phenomenon which has up to the present been wrapped in mystery—the obscure haze around the sun, "the dusky veil" in which Pickering and others maintain that a very important part, from three quarters to one third, of the solar rays is absorbed. On the other hand, Julius during the recent eclipse of 1912, has shown that less than one one-thousandth of the total radiation of the sun is due to an atmospheric envelope beyond the photosphere.

It would seem to follow from the theories enunciated here that the explanation of this phenomenon may be sought in the idea that the luminous energy, which is absorbed in the "dusky veil" in an almost incomprehensible manner, is employed in stripping flying atoms and molecules of their electrons, thus leading to the formation of cathode rays, which in turn contribute perhaps in forming the solar corona.

Let us carry a little farther this hypothesis of such a corpuscular atmosphere around the sun, even if we are obliged to venture into more uncertain territory. We know that about seventy thousand years are required by our sun to traverse in its course through space a distance equal to that which separates it from its nearest neighbor among the stars. This may serve to give one an approximate idea of the time required for the solar system to penetrate essentially different parts of space. At all events, it may be surmised that there are more or less thick clouds of flying corpuscles, as we have just imagined. It would follow, therefore, that the sun, in traversing one of the denser clouds, would be surrounded with a still thicker envelope of corpuscles or thicker dusky veil than at present, which would appreciably modify the absorption of its light and of its heat. It may also evidently be presumed that the density of the corpuscular atmosphere varies according to different causes in the interior of the sun itself, since the sun is continually projecting large quantities of corpuscles. Be that as it may, it would seem that the existence of this "dusky veil" ought to be productive of great changes of temperature in both directions, in the course of time, for the earth.

In studying the geological periods of the earth, many geologists seem now to be of the opinion that the explanation of the phenomena definitely requires an exterior cosmic cause and that the modifications of other terrestrial conditions alone will not serve to illuminate the problem. The cause of the different glacial periods of the earth may perhaps be found in the fact that the absorbing veil around the sun has considerably changed in density in the lapse of millions of years.

The hypothesis of a more or less uniform distribution of these flying corpuscles in space leads to two other important consequences which agree mutually, and one of which may be regarded as confirmed by experience. These two consequences are the following:—(1) light must be absorbed in airless space, and (2) the worlds in the universe must be infinite in number.

One of the great philosophers of antiquity, Democritus, taught that the number of celestial bodies was infinite, and that the stars, which were like our suns, were subjected to slow modifications—that they were born and that they died. His reasons for holding this opinion was evidently weak, and since his time evidence enough has been gathered to refute his theory; nearly all astronomers of our time hold that the universe is limited in extent and that it contains 20. 000,000 telescopic stars. On the other hand, Kelvin maintains, as a result of his researches, that the Milky Way must be composed of about a billion stars. But astronomers are nevertheless of the opinion that space itself is a sea of infinite ether in which the light and heat rays emanating from the sun and the stars are extinguished.

Fig. 10.—Discharge produced in a vacuum chamber of 320 liters capacity with a magnetized spherical cathode of 2.5 centimeters (1 inch) diameter.

The most important facts which can be cited in favor of a limited universe have been supplied by the researches of Olbers and of Seeliger.

Olbers demonstrated that if the density of the stars in infinite space is uniform, the entire celestial vault ought to be as luminous as the sun itself. Since this is not the case, the density of the stars must diminish with their distance from our sun. That this last supposition is at least apparently correct, is proved by Kapteyn's analysis of the light of distant stars. If, however, all space is filled with flying particles, there must be an absorption of light, which would perfectly explain the phenomena observed, when the distances become enormous, thousands of light years.

On the other hand, Seeliger has advanced another very important argument against an infinity of stellar masses. He finds that if the number of stars is infinite, such is the attraction of the masses, according to the law of gravitation, that an outer celestial body would rush upon our system with an infinite velocity. But actual measurements show that the velocity of celestial bodies rarely exceeds 100 kilometers a second; Seeliger concludes, and nearly all astronomers accept his conclusion, that the amount of matter in the universe must be limited.

Now, if, as I have supposed, the more considerable masses in space are uniformly distributed in the form of dust, in the infinity of airless space, then Seeliger's objections are welcome; for the attraction exercised on a celestial body will depend essentially on the action of the masses which lie nearest to it. Indeed, the attraction exercised by the masses on this side of a very distant portion of space will be neutralized by a corresponding attraction on the diametrically opposite side.

THE FORMATION OF GALACTIC SYSTEMS.

I will now proceed to develop still further my theory of atomic dust as set forth in the foregoing. It must be admitted that experience has demonstrated that all particles of dust, whether electrified or not, which float in space have a tendency eventually to agglomerate, and to condense into larger and larger masses. It must also be admitted that corpuscles can be deposited upon celestial bodies.

We may here refer to a few simple experiments which I have already mentioned and which render it possible completely to platinize fairly large copper plates, a very small platinum cathode being employed for that purpose. Experiments even more conclusive have been made with the positive rays of palladium. The particles of high velocity as well as those, which have, practically speaking, lost their velocity, were deposited on two parallel copper plates and formed upon them a continuous layer of palladium. The tension on the two plates was —200 volts and zero.

Under these conditions the most reasonable hypothesis seems to be that the disintegration of central bodies on the one hand and the agglomeration or condensation of small particles in space on the other hand seem to counterbalance each other; it is evident, indeed, that this agglomeration must moreover be a function of the density of the primitive dust and that it must diminish with it.

The finely divided matter proceeding from the central bodies might evidently have been produced by other agencies than by electric disintegration, but I believe that this last process (the radioactivity of central bodies in the larger sense of the term) is that which determines its evolution and gives it its character.

We know that Arrhenius maintains that cosmic dust may be carried far beyond the influence of central bodies by the pressure of light, and his assertion is certainly true. But it is not certain whether the pressure of light plays a prominent part.

Again, the researches of Ritter on the effect of stellar collision are also of great interest in this respect. He has

* Paper read before the Academy of Sciences at Kristiania, on January 31st, 1913, constituting a review and an amplification of a series of notes that appeared in the *Comptes Rendus de l'Académie des Sciences*, Paris.

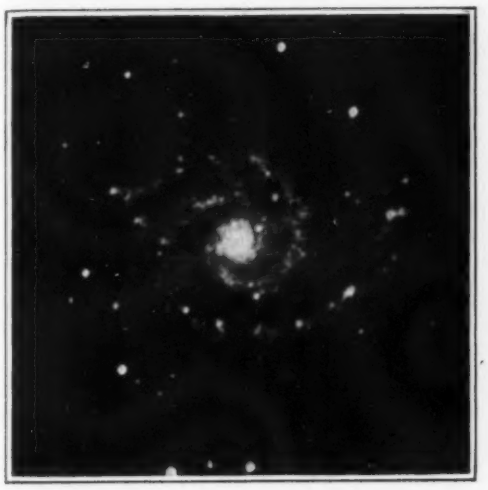


Fig. 11a.—The spiral nebula M74 in the constellation of the Fishes.

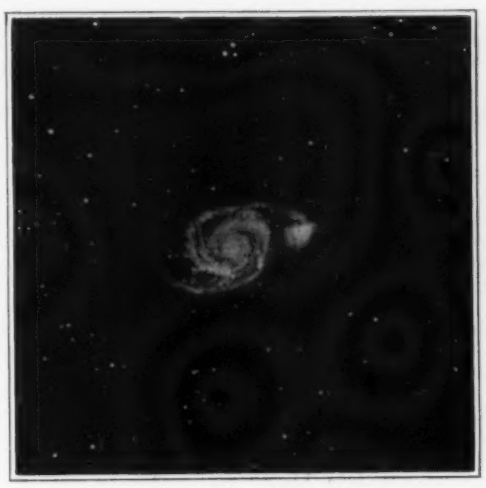


Fig. 11b.—The spiral nebula M51 in Canes Venatici.

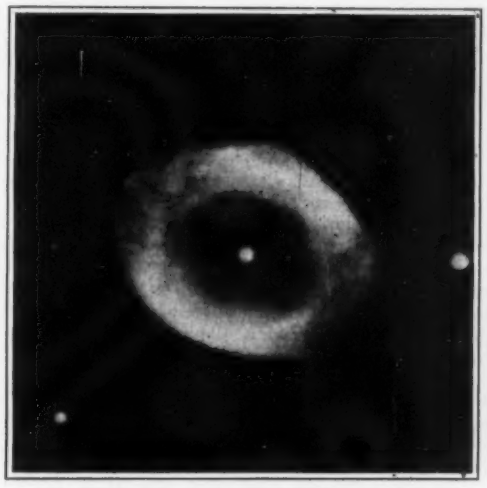


Fig. 11c.—The ring nebula M57 in the constellation of Lyra.

succeeded in proving that when two suns, moving with sufficient velocity, collide, the total mass can be scattered infinitely into space, so as to form a "centrifugal" nebulosity of constantly increasing extent. There are, however, two circumstances that render such formations very improbable, and Ritter who, by means of his centrifugal systems, tries to explain the formation of spiral nebulæ, is obliged to admit himself that such nebulæ are not by any means as rare as the theory would seem to imply.

The incredible scarcity of stars in space seems, at first blush, to argue against the probability of a collision. In order to place the matter more concretely, let a grain of sand about a millimeter in diameter represent the sun. The earth will then be a grain of invisible dust at a distance of ten centimeters. On this scale the nearest star would be another grain of dust more than twenty kilometers distant.

Furthermore, Ritter's theory demands, at the moment of collision, such a high velocity and so many other special circumstances that it is difficult to believe that such catastrophes have produced the one hundred thousand spiral nebulæ and more with which we are familiar at present.

In leaving the hypothesis here set forth on the nature of space and on its contents, I will try to find a new explanation of the formation of spiral nebulæ and of the origin of the stars known as the Milky Way.

There is much support for the view that the Milky Way may be regarded as a spiral nebula, and that spiral nebulæ, as a whole, may be designated as galactic systems. There is, moreover, the circumstance that some of the spiral nebulæ, which are sufficiently luminous, exhibit a characteristic stellar spectrum—a continuous spectrum with dark absorption lines.

According to our present knowledge the Milky Way may be described as follows:[12] It is composed of a great number of star clouds more or less distinct or separate lying almost in the same plane and encircling the celestial sphere. It is possible that the stars which seem nearest to our sun are simply members of these star clouds. Judging from the accuracy with which the Milky Way divides the sky into equal hemispheres, it is certain, in any case, that the sun lies almost in its plane. The fairly close agreement to be observed in the luminous intensity of the stars in all parts of the Milky Way would seem to indicate that our sun is almost in the center of it.

Spiral nebulæ, however, cannot be regarded otherwise than as stellar systems in evolution and not as any particular solar system in process of formation. Condensations around centers are certainly to be found in the spirals, and these condensations are distributed in the spirals like pearls on a thread. It is hardly to be hoped that the nature of the processes that take place in these spirals can be determined in a reasonable time. But the number of stellar nebulosities in all stages of condensation is so great that it is easy to select a series which will illustrate the consecutive stages of the supposed processes.

In the genesis of solar systems, as well as in the birth of a solar system, we can imagine two principal processes at work: an agglomeration or condensation of matter and then an electro-radioactive disintegration. As the first phase we imagine an agglomeration of cosmic matter of every kind, and eventually of celestial bodies, more or less extinct, the paths of which have met. This agglomeration of matter in space is admitted by everyone; but since some formation must be pointed out in the heavens in which the process in question seems to be the absolutely dominating factor, the question is not quite so simple.

I have formulated the hypothesis that planetary rings, for example, the rings of Saturn, will eventually cluster together and form satellites which will agglomerate in turn, and that the seven hundred planetoids between Mars and Jupiter will become one or several large planets in the course of time.

The star cluster in Hercules, for example, with its five thousand stars or more (see Fig. 8) would seem to be an excellent example of agglomeration. There are gaseous fogs in the Milky Way, often surrounding stars and sometimes mingled with finely divided matter, which absorbs the light from stars situated behind. These fogs are perhaps the formations in which agglomeration or the condensation is the dominant factor. A formation which is due to agglomeration and which may eventually be supposed to become a galactic system, is more likely to be found among white nebulæ, the spiral structure of which cannot be demonstrated, but which nevertheless exist in parts of the heavens in which spiral nebulæ are most frequently found. They may also be looked for in another region—the great Magellanic cloud in the southern sky, the first description of which we owe to Marco Polo, who writes that, during his voyage, he saw "a star large as a bag."

In this Magellanic cloud a wonderful collection of heavenly bodies has since been discovered. It is sufficient for my purpose to mention that there are also a large number of nebulæ, but up to the present time it has not been possible to detect in them any spiral form. Nevertheless, with the aid of comparatively low-powered telescopes, several spiral nebulæ have been found in the southern sky.

At Cordoba, Argentina, a telescope provided with a huge mirror has been installed at an elevation of one thousand meters above the sea. The time is not far distant when, with the aid of this instrument, we shall be able to determine if the great cloud of Magellan is to be considered as a second galactic system, very near our own or if it is a system of a higher order, of which spiral nebulæ in all stages, even with no recognizable spiral formation, are elements.

I now come to the second phase of my theory of evolution of stellar systems—electro-radioactive disintegration. In order to illustrate the idea which I conceive to underlie this process, I must return anew to my experimental analogues.

Many among the finest and most luminous spiral nebulæ are formed by spiral arms, usually two in number. These arms spring from a central nucleus of condensation from two diametrically opposite points and are coiled more or less regularly around the central portion. Figs. 11*a*, *b*, *c*, represent three of the finest.

Fig. 9 pictures one of the experiments made with a magnetic cathode-globe in a discharge vessel in which the pressure of gas was not so low as in some of the preceding experiments. In the magnetic equatorial plane of the globe a wholly plane luminous *disk* was not produced, as shown in Fig. 10. As a general rule several luminous spiral arms were formed, more frequently two only, which, in this latter case, sprang exactly from diametrically opposite sides of the cathode-globe. Furthermore, the experiments proved that there is only a quantitative difference in the number of arms; in the experiment represented in Fig. 10 the luminous plane is actually formed of innumerable luminous arms like the two shown in Fig. 9. It is demonstrated that at the two points from which the luminous arms spring from the globe, there is a relatively marked disintegration of matter.[13] It seems to me that this experiment throws some light on the formation of spiral nebulæ. It is possible that a planetary system revolving around a sun may originate under similar conditions and may not have been formed as previously stated. Mathematical analysis and the analogous formation of Saturn's rings, however, seem to confirm the first opinion, so far as planets are concerned. It may be imagined that the spiral nebulæ are the result of an electro-magnetic process. The nucleus, surrounded by masses of relatively thick vapor, receives, as a result of the radiation, an enormous negative tension, a high-tension polarization of perhaps billions of volts. Under these conditions the essential discharge can more frequently take place between two diametrically opposite points on the magnetic equator, and, to judge from the few experimental results obtained on discharges of this character, these discharges may be accompanied with considerable transportation of matter along the two spiral arms. The question whether the spiral form is due principally to the rotation of central body's leaving in its wake, as it were, the emitted matter, or if it is the result of magnetic action, will certainly be decided with the aid of photographs of different spiral nebulæ when a sufficient time will have elapsed. It will probably be discovered whether the nucleus has always rotated in the same direction as the spirals or sometimes in the opposite direction and whether the spirals follow the rotation of the central nucleus or not. If we may judge from experiments, the necessary magnetism for a central body to produce the *principal* phenomenon, that is to say the discharge emanating from two points diametrically opposite in the magnetic equatorial plane, need not be particularly strong. The nebulous ring of Fig. 11*c* seems to indicate a more advanced stage than that of the spiral nebulæ of Figs. 11*a* and *b*. It may be said that the central body has ceased its electric emission of matter or at least has transformed it into another phase—a less violent emission in the entire equatorial plane.

The foregoing views are based on the supposition that in the universe there is an average equilibrium between the pulverization and agglomeration of matter. This supposition seems to be the most natural, but nevertheless it may be thought that agglomeration in infinite space might, in the course of infinite time, lead to the formation of larger and larger systems originally developed from a chaos of dust. Our Milky Way, for example, to which the sun belongs, and several other similar but distant milky ways, would thus constitute a system of the third order and bear a similar relation to systems of still higher orders, as has been imagined by Swedenborg, Lambert and Charlier.

This conception is not so far removed as the first hypothesis from the theories to which we are accustomed, and it would not be difficult for us to imagine the formation of these enormous systems of a higher order if we resort to electro-radioactive disintegration.

A third hypothesis, according to which all the matter in space tends to pulverization and to greater and greater dissolution would seem, on the other hand, to be rather improbable for several reasons, if it be admitted that dust can agglomerate.

The savant who in our own time has advanced the strongest arguments in favor of the infinity of the universe and who has set forth the most original cosmogonic theories, is Arrhenius. In basing his views on certain hypotheses, he tried to show that a limited universe or one in which matter would be infinitely *diluted* could not have existed in unlimited time, and that such a universe would not correspond with our experience of the properties of matter and of energy. For Arrhenius the universe is like an enormous heat engine, working between hot sources (represented by stars) and cold sources (represented by fogs in space). He advances a novel and ingenious conception of the operation of this mechanism to support the view that worlds are probably recreated eternally.

(*Concluded on page 32.*)

[12] See A. R. Hinks, "Astronomy," London, 1911.

[13] Sometimes the spirals emerge from the equatorial plane and then coil in *helices*, one around the north hemisphere, the other around the south hemisphere of the central body, or the two toward the same hemisphere.

The Production of Caustic Alkali and Bleach*

A Review of Recent Developments

By D. J. Allmand, D.Sc.

THE most important advances made in late years in the technical electrolysis of alkaline chlorides for the production of caustic alkali and chlorine are perhaps due to Dr. Jean Billiter, privatdozent in the University of Vienna. Some years back he designed a diaphragm cell which is being exploited by Siemens & Halske, and recently he has invented a modified form of the well known bell-jar cell, which is undoubtedly, taken all in all, one of the most efficient cells now operated technically. The Billiter-Siemens diaphragm cell I propose to mention briefly only, as full accounts of it are available elsewhere, and shall devote most attention to the Billiter "membrane" cell, the first installation of which started work early this year.

BILLITER-SIEMENS CELL.

Most diaphragm cells in technical use have vertical diaphragms (e. g., Hargreaves-Bird, Townsend, Finlay). Billiter, however, has returned to the use of horizontal diaphragms, such as were formerly employed by Le Sueur and by Carmichael. He has compared elsewhere the relative advantages and disadvantages of the vertical and horizontal arrangements.

A horizontal diaphragm is more slowly attacked chemically, as it remains more or less saturated with the alkali which migrates upward from the cathode situated immediately underneath. This is particularly important when making strong alkaline liquors. Further, the hydrostatic pressure on it is uniform at all points, not varying with the height as in vertical diaphragms. This means a more uniform flow of liquid through, and consequently a more efficient checking of the movement of the OH ions toward the anode.

There are corresponding structural disadvantages. The floor-space needed is greater. Further, the insides of the cells are less easily accessible and the anodes are necessarily of more complicated construction.

The active diaphragm material in the Billiter-Siemens cell consists of a mixture of asbestos wool and $BaSO_4$, spread out evenly on top of a sheet of woven asbestos cloth, which in its turn rests on the ironwire net-work which constitutes the cathode. The function of the asbestos cloth is merely to support the $BaSO_4$ mixture and to prevent its being displaced by the lively hydrogen evolution. The cathode makes contact with the iron bottom of a trough, the sides of which are lined with cement, and the anode chamber is formed by a non-conducting bell-jar, which is securely cemented around the edges of the diaphragm. An important feature of the cell is the arrangement for heating the electrolyte by means of earthenware pipes through which hot liquids run, these being immersed in the brine at the top of the bell-jars.

Cells have been made carrying up to 3,000 amperes at a current density of 4 to 6 amperes per square diameter. Working at 89 to 90 degrees, 12 to 16 per cent NaOH or 18 to 20 per cent KOH can be made at a 95 per cent cathodic currency, employing 3.5 volts.

An interesting laboratory study of the Billiter-Siemens cell has been recently published by Muhlaus. He finds that the $BaSO_4$ used for the diaphragm is best precipitated hot. No change of size of grain when in the hot liquors of the Billiter cell is then likely to take place, and a regular and uniform flow is thus assured.

The highest current density permissible is about 6 to 7 amperes per square decimeter.

Above this limit, disintegration sets in. Using 30 to 32 per cent brine at ordinary temperatures, the following figures were obtained:

Concentration of Alkali.	Current Efficiency, Per Cent.
3n	98-99
4n	95-97
5n	80-85
6n	75

The chlorine gas fell in purity from 99.5 per cent to 92 per cent as the alkali concentration was increased. The oxygen produced exceeded the amount of CO_2. The solid caustic resulting contained considerable quantities of $NaClO_3$ if produced from liquors stronger than 4n. The best results on the whole were given when making 4n. NaOH at a current density of 4 amperes per square decimeter. Raising the working temperature to 70 to 80 degrees improved both energy efficiency and purity of alkali.

The Billiter-Siemens process is now operated as follows:

(*a*) In Aschersleben, Saxony, by the Kaliwerke Aschersleben A. G. Ten 2,000-ampere units.

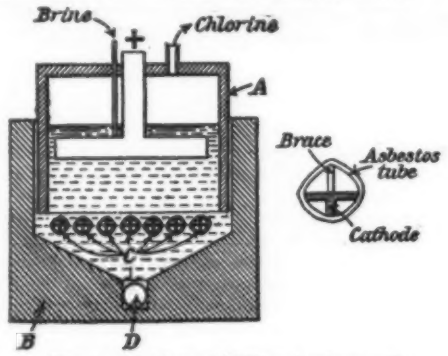


Fig. 1.—Section of Billiter-Leykam cell.

(*b*) In Höchst, by the Farbwerke Höchst.

(*c*) In Brückl, Bosnia, by the Bosnische Elektrizitäts A. G. Sixty-four 2,500-ampere units.

(*d*) In Krumau, Bohemia, by Ignaz Spiro and Söhne. Thirty-two 500-ampere units.

(*e*) At Niagara Falls, by the Niagara Alkali Company. A 1,000-kilowatt installation of 3,000-ampere units.

A number of plants are also being installed or enlarged. The Niagara Alkali Company (which has succeeded the old Roberts Chemical Company) is at present increasing the size of its plant from 1,000 to 3,000 kilowatts. It has also been made known that a new factory for caustic alkali and bleach is being erected, commencing with 78 2,000-ampere units, and that a textile factory is installing twenty-four 100-ampere units

BILLITER-LEYKAM CELL.

In this cell Billiter has successfully modified the bell-jar process, placing the cathodes (hooded to collect the hydrogen) immediately *underneath* the bell-jar, and not around its sides, as in the Aussig cell. Similar constructions had been formerly suggested by Richardson and by Bein, but had achieved no technical success.

By doing this, Billiter gains an important advantage. In the ordinary bell-jar, both flow of liquid and flow of current change in direction at the

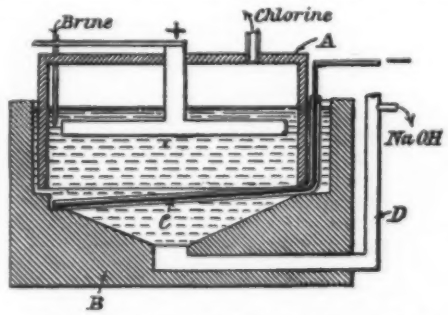


Fig. 2.—Section of Billiter-Leykam cell.

lower edge of the bell-jar. This results in non-uniformity of current density and liquid flow in the different parts of the bell-jar section. At some points liquid will be flowing more quickly than is necessary to overcome the OH_1 migration toward the anode, at other points the contrary will be true; the movement of the OH'ions will predominate, and the current efficiency will fall. This last statement particularly holds for those parts of the bell-jar section farthest removed from the walls, where the current of liquid is exceedingly slow. The larger the bell-jar, the greater proportionately is this disturbance. It also increases rapidly with current density. The consequence is that the units (bell-jars) at Aussig are very small, and can only be worked at a low current density, furnishing weak alkali. Such a plant requires much floor space for its output and the labor charges are high.

In the Billiter cell, this change of direction and the resulting irregularities are avoided, the motion of the brine being directly opposed to that of the current lines until it has passed the cathodes. The consequence is that high current densities can be used, stronger caustic liquors produced, high current efficiencies obtained, and large units constructed. At the same time, the advantage of the bell-jar cell, the absence of diaphragms, is essentially retained. For, though the *current* must all pass through the hoods which cover the cathodes, this is not true of the electrolyte. Most of it passes directly through the spaces between neighboring cathodes, and is charged with caustic by diffusion from the concentrated alkali which fills the cathode hoods. Not only does this alkali protect the hood material (in practice, woven asbestos) against chemical action of chlorine compounds, but suspended matter present in the brine is *not* filtered out, as happens in diaphragm cells, and it is not necessary to purify the brine in any way. The asbestos hoods are made of as coarse a structure as is consistent with their function of leading off the hydrogen gas, and affect the voltage to a very slight degree only. Finally, the cell is heated in a similar fashion to the Billiter-Siemens cell, and the voltage thus lowered.

The essential parts of the Billiter-Leykam cell are shown diagrammatically in Figs. 1 and 2. A is the bell-jar inverted in the cement trough *B*, and provided with anode outlet for chlorine, inlet for brine and heating arrangement. The cathodes *C* are arranged below the bottom level of *A* and consist in practice of T-iron. They are inclosed separately in long woven asbestos tubes which are suitably braced in order to avoid deformation by the evolved hydrogen, and are slanted sufficiently to allow the gas to stream away readily. These cathodes project out into a side compartment of the cell as shown, from which the hydrogen can, if necessary, be collected.

The causticized brine flows off through *D*.

The Austrian rights to the Billiter bell-jar cell have been purchased by the paper manufacturers Leykam-Josefsthal A. G. The first plant has been erected in their mill at Gratwein, a village on the Austrian Southern Railway, a few miles from Graz, has been in continued operation since early 1912, and has given every satisfaction. Some 1,700 to 1,800 kilos of active chlorine are produced daily, and the whole plant uses about 400 P. S.—350 P. S. for the cells and 50 P. S. for auxiliary pumps, fan, etc. Power is purchased from a company at 150 kr. ($31.25) per P. S. year. After converting into direct current, and reckoning all losses in leads, etc., the cost comes to 180 kr. ($37.50) per P. S. year.

The plant consists of 561,200-ampere units, 50 of which were working at the time of my visit last July.

The cells are 5.5 meters long, 1.1 meters broad (internal measurements), and about 1.3 meters high. The side walls commence to slope inward about 70 centimeters below the top of the cell. They are built of reinforced concrete, the upper part being lined with earthenware bricks set in cement.

They are provided with three cement lids, each of which carries eight anodes.

The anodes are of Acheson graphite ($1.0 \times 0.18 \times 0.05$ meter), each being led through its lead by means of two graphite rods. The lids are cemented on to a shallow shelf cut out of the wall of the cell by means of ordinary putty, which stands the action of chlorine very well and always remains fairly soft. Putty is also used at the points where the anodes pass through the lids, as the weight of the anodes is not borne by the latter, but by the copper leads above. Each anode takes 50 amperes at a current density, assuming lower and side surfaces to be active, of about 1.6-1.7 amperes per square decimeter.

The cathodes are of T-iron and inclosed in woven asbestos tubes. These taper down slightly toward their closed lower ends, and the whole is braced by the insertion of a wedge-shaped strip of asbestos cement. The tubes pass through holes in the

*Paper read before the Faraday Society in London.

dividing wall into the side compartment of the cell as indicated in Fig. 1. Two iron rods attached to each T-iron cathode take the current to the copper leads above. The hydrogen is allowed to escape. The cathodes are, of course, about 1 meter in length, and the mean breadth of the asbestos tubes is about 5 centimeters. Between each tube there is a space of 5 to 8 millimeters. The upward slope of these tubes is about 2 centimeters per meter,

The brine (moving from a reservoir under gravity) is led to a distributing box situated above the cells. From this it proceeds by way of a series of short capillary tubes (1.5 millimeters bore) to 22-inch tubes, which pass through the cell lids, and is thus fed in between the anodes. Regulation of the main supply to the cell is effected by means of a rubber tube and clip. This arrangement acts on the whole very satisfactorily, though the capillaries sometimes get stopped up. The causticized brine is drawn off from one side of the cell by means of siphon overflows. Three are provided, but one only is used in practice.

The heating arrangement used by Dr. Billiter in his diaphragm cell, though available for all other installations of his "membrane" cell, cannot be used at Gratwein. (The patent rights are not there available). The cells are, therefore, provided with a heating arrangement which employs steam, the details of which, however, I cannot divulge here. When I was at Gratwein, the cells were being mostly worked at room temperature, while those few which were being heated were working at a temperature of 65 deg. Cent. to 70 deg. Cent.

The cells are arranged in four rows, two rows being worked in series, and are insulated by glass resting on concrete supports. Beneath the cells are arranged the chlorine and brine pipes, and a channel for the caustic liquors. The chlorine pipeline is constructed of cement, junctions being made by covering the ends with a cement box and filling up with asphalt. The current leads are of copper, those connecting the cells of circular cross-section and 3 centimeters in diameter. They are all painted with a composition stable against chlorine and acid fumes, as are also the tin tubes and rubber connections referred to above. The cells are worked under slightly reduced pressure (½ centimeter of water), and, as a matter of fact, no smell of chlorine was noticeable. Ventilation can be effected, if necessary, by blowing air in through the agency of a fan driven by a horsepower motor. A traveling-crane is provided to facilitate lifting off the tops of cells, etc.

Saturated brine is used, prepared in the simplest way. A long cement trough is filled with large lumps (20 to 40 centimeters) of crude salt. Waters enter continuously at one end, and saturated brine leaves at the other. It is not purified, and can be sent straight to the cells. The average cathode liquors produced contain 12 to 13 per cent NaOH and about 20 per cent NaCl. By decreasing the rate of flow of brine, 16 per cent NaOH can readily be made. Up to 350 liters of brine per cell are causticized in 24 hours. The liquors are first evaporated in two vacuum pans, furnished by the Skodawerke A. G., Pilsen, and similar to those used in sugar refineries. In these they are successively brought to 30 deg. Bé. and 40 deg. Bé. Then by means of a Kaufmann rapid evaporator they are brought to 50 deg. Bé. before going to the melting-house. The final product, which will probably be later somewhat improved upon, contains 97 per cent NaOH, 1.2 per cent Na_2CO_3, and 1.8 per cent NaCl. The chlorine is diluted and absorbed in milk of lime.

Cells which are worked at room temperature take about 4 volts. Those I saw working at 65 to 70 degrees require 3.4 to 3.5 volts. Long continued experiments carried out with a 250-ampere unit have shown that at the normal working temperature of 85 degrees the voltage falls to 3.1 volts (*plus* in all cases the voltage drop in the leads). The cathodic current efficiency is about 92 per cent for 3n to 4n alkali.

It remains to be added that wear and tear in the cells are very small. Under normal working conditions the anodes lose about 1 millimeter in thickness at their bottoms and sides in two months. Suspended matter in the brine settles on the bottom of the cells, and the asbestos hoods remain unaffected. Finally, when once matters are adjusted, the whole system works automatically. The actual cell-room in Gratwein is worked by shifts of one workman only, whose duty it is to adjust the rates of flow in the different cells. Moderate fluctuations in rate of flow of brine or in current density result in a change in the alkalinity of the liquors produced, and in a corresponding *small* change in current efficiency. The cells at Gratwein work at a current density between the electrodes of about 2 amperes per square decimeter only. With cells working at 85 degrees the most convenient figure, according to Billiter, is 4 to 6 amperes per square decimeter; but, by suitably varying the other conditions, 14 amperes per square decimeter can be employed.

The withdrawal of 350 liters of catholyte per cell per 24 hours corresponds to a movement of the brine of about 0.00007 centimeter per second. The OH ions in that part of the catholyte between the electrodes will have a velocity anodeward of just about the same magnitude. (E. g., assuming the cell to work at room temperature, the conductivity of the electrolyte would be about 0.5 reciprocating ohm per cubic centimeter, the velocity of the OH ion at a voltage gradient of 1 volt per centimeter, 0.0018 centimeter per second, and the actual velocity $0.02 \times 0.0018 \div 0.05 = 0.000072$ centimeter per second). This close approximation between the two opposing velocities, with the consequent straying of OH ions toward the anode, is of course the chief cause of the 8 per cent deficiency in current efficiency, as the amount of chlorine which dissolves in the concentrated brine, and which would thus tend to be carried to the cathode, is very small.

In conclusion, I will again emphasize the chief characteristics of the Billiter-Leykam cell. They are:

(1) Freedom from diaphragm troubles.

(2) Use of impure brine.

(3) Automatic working, great adaptability, and low attendance charges.

(4) Alkali (3n to 4n) strong compared with most other non-mercury cells.

(5) With heated cells, lowest energy consumption per ton of product of any of the electrolytic cells now working on a large scale.

Regulation of the Heat of the Body in Hot Climates*

In all temperate climates and, if certain exceptional cases are noted, in almost all climates in which mankind is engaged in the usual activities of life, the temperature of the human body is higher than that of the environment, so that there is a tendency toward continuous loss of heat from the surface of the body. Except in so far as it is prevented by the insulating devices of clothing, this loss takes place in part by convection, that is, by warming the layers of air in contact with the body, as well as by radiation whereby there is an exchange of heat between the surface of the body and that of surrounding cooler objects. When there is occasion for the removal of a larger amount of heat, this is accomplished through the function of perspiration. In the evaporation of sweat a large amount of heat becomes latent and is removed from the body. The chief factor which may interfere with this procedure is the impeding of the evaporation by the presence of an atmosphere already saturated with water vapor so that the sweat can no longer be converted into the gaseous phase.

Few persons realize that there are, nevertheless, inhabited regions in which the temperature of the surrounding air is not lower than that of the body. In parts of India, for example, during the hot weather in March, April and May, the maximum temperature is daily seldom under 38 deg. Cent. (100.4 deg. Fahr.), and in some places it rises to over 43 deg. Cent. (109.4 deg. Fahr.) for long periods. Usually such habitable areas experience a very low percentage of moisture in the air. Wet heat is not usual, since with the rains the weather becomes cool.

It is well known that the body temperature can be maintained at its normal height in an atmosphere much higher than 37 deg. Cent. (98.6 deg. Fahr.), in spite of the fact that the production of heat is still going on in the organism. It is said that a man can stand exposure to a temperature of 90 deg. Cent. (194 deg. Fahr.) or even 120 deg. Cent. (248 deg. Fahr.) for a considerable time provided that the air is dry. If the outside temperature be above that of the body, heat is actually added instead of lost; and this additional heat is greatly increased by exposure to a very hot sun or wind. Inasmuch as radiation and conduction are available as cooling agencies only when the outside temperature is below that of the body, it is a matter of no little moment to understand what the organism is called on to do in order to prevent any marked rise of internal temperature. That an adjustment does take place is assured from the fact that during extremes of dry heat no great discomfort is felt by healthy persons; and it is stated on good authority that fairly hard physical work is possible in the sun, even with a "shade" temperature o 43 deg. Cent. (110 deg. Fahr.) or more. Here the organism must depend solely on evaporation as a cooling agent; and this function must be sufficient to remove all the heat added from external sources as well as the heat due to internal metabolism. In a Turkish bath the loss of weight, represented almost entirely by water, may be at the rate of at least two pounds every hour.

Dr. E. H. Hunt, medical officer to the N. G. S. Railway, who resides in Deccan, India, where extremes of heat like those mentioned prevail, has furnished interesting data as to how one becomes adjusted to the physiologic and hygienic conditions thus created.[1] The heat contributed by the combustion of the ordinary food-supply sufficient to maintain nutritive equilibrium may be judged from its fuel value. If this is put at 3,500 calories for an active working man, a calculation shows that the amount of water the evaporation of which will absorb this heat at body temperature is 6 liters (about 6 quarts). Water must therefore be taken into the body in food and drink to supply this requirement in addition to what is lost by excretion, is wasted by inefficient perspiration, or is needed to remove the heat actually added to the body from without, in the hot climates referred to.

Such hypothetical estimates have been compared by Dr. Hunt in India with actual observations made during an exceedingly hot and very dry period when, for some hours at midday, the lowest temperature which could be secured in tents under trees was 42.8 deg. Cent. (109 deg. Fahr.). All dry objects were as hot as this or hotter and were uncomfortable to handle. The mercury in the thermometer fell at once when a hand was placed near it, or if it were breathed on. Until about midday the party of investigated healthy Europeans remained in the sun with no shade whatever, a considerable amount of physical exercise being taken. Such a life, we are told, is led by hundreds of Europeans in India, customarily with a gain rather than a loss of health. When health suffers it is usually through the incidence of infectious disease. None of the party, using strict moderation, consumed less than three gallons of liquid per day. When the activity and considerable exposure to the extremes of heat are taken into account in this experience, which probably represents an approach to the limit of comfort, the fluid intake is not far removed from the hypothetical estimate, based on the many data at hand.

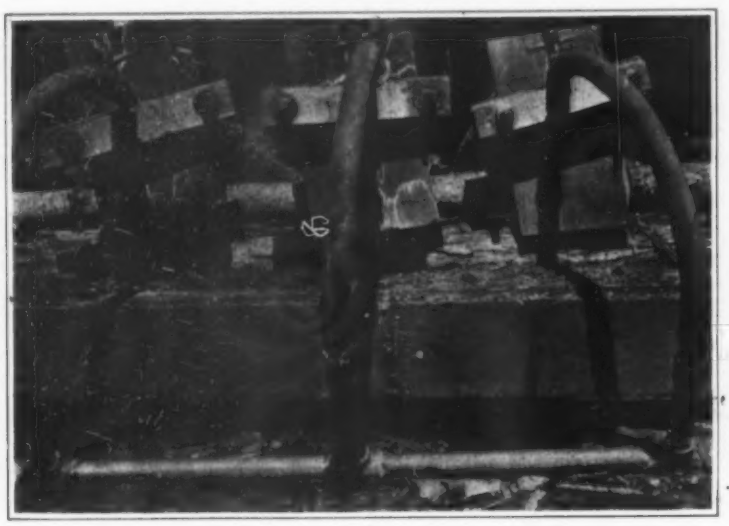
It is obvious that in such extremes of dry heat any failure of perspiration must lead to instant and grave risk. This failure may result from an insufficiency of drinking-water. It may equally result, as Dr. Hunt maintains, from pathologic processes incident to slight malaria, early typhoid, or any other process by which heat regulation is upset. He adds that he has not come across any case of pure "heat-stroke" or sunstroke in a proved healthy person. A man might suffer from but slight fever while indoors and might be unaware that he was ill; yet his whole regulation might completely fail if he were at work in the sun under the numerous conditions which involve an extreme effort even for the healthiest.

The main regulation of heat loss takes place by the control of the nervous system over the cutaneous circulation and the sweat-glands. When this fails, the temperature must speedily rise above the normal in these hot climates. General excitability is evinced and metabolism is stimulated so that a "vicious circle" is established. There is not even any compensation by lessened heat production. In "wet heat" the limit of safety is speedily reached. When the air is already more or less saturated with moisture, as indicated by high wet-bulb thermometer readings, evaporation is slow and inefficient, and danger ensues even during rest. The excess of sweat secreted and any increase in the amount of water consumed under such conditions merely increase discomfort rather than facilitate the proper heat regulation of the body.

The large amount of water absolutely required and actually consumed by men in these hot climates has not been appreciated adequately in any quantitative sense. Experiments by Hunt have demonstrated that a healthy man carries in his body a large reserve of water mainly stored in muscle and so readily available that the percentage of water in the blood is not appreciably diminished even when several liters of water have been lost by sweating. If, however, it is extensively drawn on, replacement seems to occupy many hours, and this delay is an important factor, forming a strong argument against any restriction of drinking which would cause undue or needless use of the stored water of the human body.

* Reproduced from the *Journal* of the American Medical Association.

[1] Hunt, E. H.: The Regulation of Body Temperature in Extremes of Dry Heat. *Jour. Hyg.*, 1912, xii, 479.



End view of logs being treated by the Boucherie process.

Boucherie wood treating plant. Side view.

The Development and Status of the Wood Preserving Industry*

Notes on the Art as Practiced in America

By E. A. Sterling

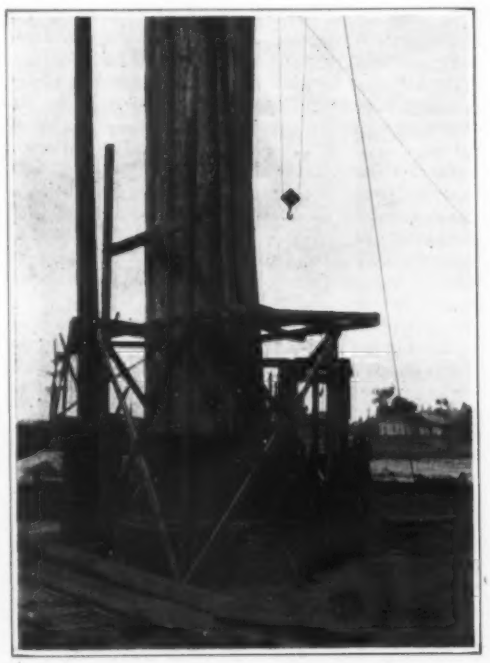
THE literature on the subject of wood preservation in America is voluminous, but so fragmentary that a summarized review of the developments and present status of the industry is, perhaps, justified because of the importance of the question to scientific and commercial interests. The information available is largely in the form of association and government reports and trade journal articles; while much that would be of value is filed away in private or confidential reports of railroad companies and wood-consuming concerns. There is little merit attached to a compilation of the essential facts on the subject and no opportunity for originality save in possible conclusions which may be drawn. Those intimately associated with the industry will find little of interest in a general paper on wood preservation; yet its close relation to applied chemistry gives the subject considerable importance at an international meeting of chemists, and particularly so to foreign visitors who are not familiar with conditions governing the industry in America.

Economy in the use of material should be a fundamental in manufacturing and engineering enterprises; yet in the case of wood wasteful use rather than economy has prevailed for many years. The natural timber resources of America were so great that rapid exploitation followed the development of the country as railroads were pushed farther west, with the result that enormous quantities of timber have been thrown on the market at comparatively low prices. This condition prevailed up to about a decade ago and the general acceptance of preserving process to increase the life of wood material did not occur until local timber supplies in many regions were greatly depleted and prices reached a point where longer life from the wood used was essential to efficient management.

The first attempts to increase the life of wood by chemical treatment took place about the same time that apprehension was first felt regarding the exhaustion of the natural forest resources. In fact, scanty or diminishing timber supplies, even up to the present time, have been the incitement for preservative treatment. During the early days of settlement, little or nothing was known about the enormous forest resources lying farther West, and prior to the opening up of these western regions by the railroads, it seemed apparent to a few far-sighted men that the available timber in the region already settled would ultimately become exhausted. Even before wood preservation was actually attempted in America, and as early as 1800, the Federal Government recognized the importance of certain kinds of timber, particularly white oak, red cedar and long leaf pine for naval construction, and set aside several reserves aggregating about a quarter of a million acres for naval purposes.

In 1865, or about the time the first serious consideration was given to wood preservation, Rev. Frederick Starr discussed the American forests and their preservation, and in a statement which was almost prophetic in its wisdom, said: "Like a cloud no bigger than a man's hand just rising from the sea, an awakening interest begins to come in sight on this subject (forest preservation), which as a question of political economy will place the interests of cotton, wool, coal, iron, meat, and even grain beneath its feet. The evils which I anticipate will probably increase upon us for thirty years to come with ten-fold the rapidity with which ameliorating measures shall be adopted. The nation has slept because the gnawing of want has not awakened her. She has had plenty and to spare, but within thirty years she will be conscious that not only individual want is present, but that it comes to each from permanent national famine of wood." There is probably no direct connection between the early anticipations of a timber shortage and the first attempts at wood preservation, but it is interesting that the preservative treatment of timber to increase its life was urged about the same time as forest preservation; and that they both failed of general acceptance at the time, because of the vast quantities of cheap timber available.

The first American publication of much value pertaining to wood preservation is probably a paper by John Bogart in the Transactions of the American Society of Civil Engineers, Vol. 8, January, 1879. Prior to this a Treatise on the Preservation of Timber by William Chapman, Civil Engineer, published in London in 1817, was referred to by American engineers. This latter treatise contained records of experiments with twenty-one different preservative compounds, none of which is in use to date. In 1880, the American Society of Civil Engineers appointed a committee to consider the preservation of timber, and after five years' work their report was submitted and embodied in three bulletins under the dates of July, August and September, 1885. Various miscellaneous papers and reports were prepared by different individuals and associations during the next ten years, and in 1895 appeared one of the first complete railroad reports on the subject by a committee appointed by the Association of the Transportation Officers of the Pennsylvania Railroad. During this same ten year period, or from 1885 to 1895, there was considerable actual development in the construction and operation of treating plants throughout the country.



Treating cedar poles. View showing frame for holding poles in place.

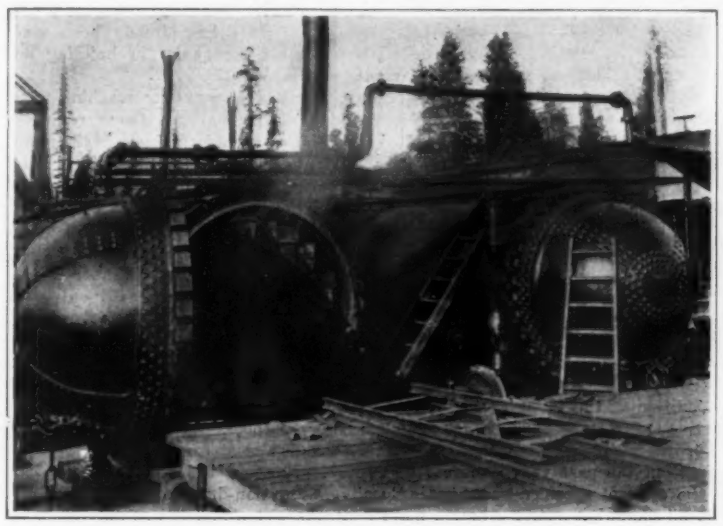
The first recorded use of treated ties is of kyanized chestnut laid in the Northern Central Railroad in Maryland in 1838, which were still sound when examined eleven years later. Kyanized oak ties laid in the tracks of the Chesapeake and Ohio Railroad in 1840 were sound when examined fourteen years later.

The first treating plant, worthy of the name, was probably that built at Lowell, Mass., in 1848, by the proprietors of the locks and canals at that point. The plant consisted of two wooden tanks, each fifty feet long, eight feet wide and four feet deep, in which the lumber was immersed in accordance with the kyanizing process using bi-chloride of mercury. Prior to 1895, several temporary plants were constructed by railroad companies, among these being one established by the Central Vermont Railroad Company in 1856; another by the Erie Railroad in 1861, at Owego, N. Y.; another by the Union Pacific in 1867, at Omaha, and one by the Philadelphia, Wilmington and Baltimore Railroad in 1863, all of these being for the use of zinc chloride by the burnettizing process. The first permanent railroad plants were built in 1875 and 1876, one being constructed by the Louisville and Nashville at West Pascagoula, Miss., and still in operation, and the other by the Houston and Texas Central Railroad Company. Both were creosoting plants.

In spite of the many attempts at wood preservation during the past forty years, the rapid and permanent developments have mostly occurred during the past ten years. In 1900, there were eleven plants in operation, while at the beginning of 1912 there were about one hundred, with several more under construction or authorized. Prior to the year 1900 the most definite developments were in the West where scarcity of timber forced the railroads to adopt measures by which longer life could be given their cross ties. We thus find that the Southern Pacific Railroad has a burnettizing plant which has been in operation since 1887, while a plant using the same process was put into service by the Sante Fé in 1885. The latter road has since adopted the Reuping creosoting process. Several commercial plants were also built in the western part of the United States prior to 1900, but the general adoption of preservative treatment throughout the United States, particularly by the Eastern railroads, has all been during the last ten years.

In Canada the developments have been even slower than in the United States and it is only within the past two or three years that treating plants of any size have been put into operation. At the present time, the Canadian Pacific Railroad and the Canadian Northern either use treated ties from plants already in operation, or have arranged for the construction of plants. In

* Paper read before the 8th International Congress of Applied Chemistry.



High-pressure cylinder for treating railway ties.

View of kiln and steaming cylinder. (The kiln is seen through the cylinder).

Mexico and South America little or nothing has been done, although some of the Mexican railroads have experimented extensively with crude oil and several plants have been built. In South American countries there are no plants, as far as the writer's knowledge goes, but large quantities of creosoted material have been shipped from plants in the United States for use, particularly in marine work.

The present status of the wood preserving industry in America is very encouraging, and although the start was long delayed much economy will result from the enormous amount of work now being done and the drain on the timber resources will be very materially reduced. At the beginning of the year 1912, 101 plants were listed by the American Wood Preservers' Association. Of this number 25 are owned and operated by railroad companies, and 12 in addition are maintained solely for railroad work. The remainder do a general commercial business.

The industry in the United States, up to the present time, has been built up largely on railroad cross ties, yet out of the 148,000,000 ties used in 1910, according to census figures, only 26,000,000 or about 18 per cent received preservative treatment. This however is an increase of 275 per cent over the number treated in 1905. During the year 1910, there were also treated approximately, 133,000,000 board feet of lumber, which represents only one third of one per cent of the total consumption. The total output of all treated material in 1910 amounted to slightly over 100,000,000 cubic feet, which was 500 per cent more than was treated in 1904. To treat this amount of material in 1910 there were consumed approximately 17,000,000 pounds of zinc chloride and 63,000,000 gallons of creosote, 71 per cent of which was imported.

In 1911, according to statistics compiled by the American Wood Preservers' Association, a total of 110,372,660 cubic feet of material was treated in the United States, this being an increase of 10 per cent over the previous year, and a 62 per cent increase over 1907. Of this amount 84,672,370 cubic feet consisted of cross ties, 3,910,740 cubic feet of piling, 1,085,971 feet of poles, 10,140,474 cubic feet of paving blocks, 6,831,416 cubic feet of construction timber and 2,568,857 cubic feet of lumber and miscellaneous material. By kinds of treatment 73,558,621 cubic feet were treated with creosote, 29,501,665 feet with zinc chloride and 7,312,374 feet with zinc chloride and creosote.

Treating poles in tanks made from creosote iron drums.

The kind and character of the timber treated varies greatly in different sections of the country. In the northeastern States the bulk of the material is hardwood, including red oak, beech, birch, maple and pine, which is shipped in by water from South Atlantic States. In the Lake States and the upper Mississippi Valley the cross ties treated are almost exclusively hardwood of the species above named. In the South Atlantic and Gulf States, and to some extent in the Southwest, pine is used almost exclusively; while in the lower Mississippi Valley and adjacent territory, both black and red gum are being treated with apparent success. In the West and Northwest the wood most largely used for treatment is red fir. Considerable difference of opinion exists as to whether the so-called sap pine is suitable for cross ties. It is used extensively by some of the railroads in the South and Southwest, where traffic is comparatively light, but the experience of the railroads in the Northwestern States, where the traffic is heavier, indicates that the soft sap pine does not hold the spikes well and is not sufficiently resistant to rail cutting.

Even a summarized review of the various preservatives and processes used and their development or abandonment during the past forty years would occupy too much space and would not be of particular value. In spite of the many experiments made in Europe and the knowledge based on European experience that a very large percentage of the preservatives tried were of little or no value, American inventive spirit was not content without developing many additional methods and the Patent Office records show several hundred processes and preservatives which have been tried. The report of the American Society of Civil Engineers in 1885 treated specifically the processes which had received some recognition abroad. Those considered worthy of attention at that time and which had been tried in the United States, were the Kyanizing process, using chloride of mercury; the Bethell process, using creosote oil; the Burnettizing process, using chloride of zinc, and the Boucherie treatment, by which pyrolignite of iron or sulphate of copper was introduced into standing trees and later into cut timber.

In addition to the processes above listed there are records of American experiments prior to 1882 with

Lowering a pole into butt apparatus.

Portable wood treating plant.

some thirty-five additional miscellaneous processes. Among these we find arsenic and salt, pyroligneous acid, natural soil, red lead, fish oil and tallow, tar and cement, common salt, lime, and carbolic acid. Either because of their high cost or their failure to prove effective, practically all of these earlier processes have been abandoned.

At the present time only two standard preservatives are in general use in the United States, namely, creosote and zinc chloride. Of these creosote seems to be gaining ground steadily; while zinc chloride is used mainly in the semi-arid regions of the middle West or in combination with creosote. It should be mentioned that the Santa Fé Railroad is making very extensive experiments with a crude oil which carries a high percentage of asphaltum. While possessing no toxic properties this oil seems to effectively close the pores of the wood and act as an inert filler against the entrance of air, moisture and fungus spores. In later experiments a mixture of natural asphaltic oil and creosote has been used. In addition to the accepted preservatives named, many manufactured preservative compounds are on the market. Most of these are intended only for superficial application with a brush or in open tanks. The claims in many cases are grossly exaggerated, but some of the preparations have merit because they contain preservatives of real value.

Although the number of accepted preservatives has been reduced to two or three, several different and distinct processes for introducing the solutions into the wood are in general use. Each of these has its ardent advocates and each, depending on the conditions under which it is used, has points of merit which can hardly be disputed. In a country with such diversified conditions as the United States, it is natural that what would apply and be best under one set of conditions would not prove satisfactory under another, hence it follows that if the different processes are used or modified wisely to suit the local conditions favorable results may be expected. There are also plenty of charlatans in the wood preserving business, so that from time to time consideration has to be given new forms of treatment and new processes which are worthless or hardly likely to have as much merit as the treatments which have been thoroughly tried and accepted.

As detailed accounts of nearly all existing processes are available, both in this country and in Europe, it would not be advisable to repeat the descriptions. The following table summarizes the processes now used in America. The high pressure processes are most generally used, and while the so-called open tank or atmospheric pressure and the low pressure treatments have been used quite extensively by small concerns which could not afford expensive plants, it may be expected that the pressure treatment will prevail almost universally within a short time.

The various treatments or processes now in use may be briefly summarized as follows:

High Artificial Pressure Processes	Full Cell	Bethell—creosote Burnett—zinc chloride Wellhouse—zinc chloride, zinc and tannin Card—zinc chloride and creosote Crude oil—natural asphaltic oil[1] B & M—zinc chloride and aluminium[1] salts
	Empty Cell	Reuping—creosote Lowry—creosote
Atmospheric Pressure Processes	Full Cell	Soaking in cold preservatives Soaking in hot preservatives. Alternate hot and cold treatments
	Empty Cell	Hot, cold and hot treatments Hot and graded cooling treatment
Low Artificial Pressure Processes	Full Cell Empty Cell	

In addition to the above, kyanizing and vulcanizing plants are still operating in New England, the latter being a rapid drying or baking process without the use of a solution.

The question of specifications and standards and many important technical points requiring consideration do not come within the province of this paper. As part of a general discussion it may be stated that zinc chloride, being a mineral salt, can be manufactured to meet definite specifications. There is little difficulty in specifying the quality of chloride desired for preservative treatment and procuring from the manufacturers the grade desired. Since crude oil is a natural product it is necessary to procure the supply from oil wells which produce the quality desired, namely, that with a very high percentage of asphaltum. The oil which has been found most suitable for preservative treatment is that known as Bakersfield oil from southern California, also from certain districts in Mexico.

In the matter of creosote specifications much more difficulty is encountered. Coal tar creosote being a by-product of a by-product, and not manufactured exclusively for preservative purposes, varies greatly in its chemical composition and except by re-distillation cannot be made up to meet too strict specifications. The consumers have rather definite ideas as to the quality of creosote desired, but unfortunately it has been necessary to base the specifications on the kind of oil available, both abroad and in this country, rather than to make arbitrary standards and expect the manufacturer to meet them.

The American Railway Engineering Association has attempted to maintain a high standard for creosote, and for some years its specifications have been the basis on which most of the oil was bought and sold. It is well understood, however, that a considerable percentage of the oil used has not met the stated requirement, and that differences in methods of coal tar distillation between individual plants and between domestic and European practice led to wide variations in the quality of the creosote produced. In recognition of this situation and owing to the enormous increase in the consumption of creosote and the apparent scarcity, the Railway Engineering Association within the past year added two additional grades to the original specifications. These are intended to cover oil somewhat poorer in quality, which it is necessary for the consumers to use in order to procure an adequate supply when grade No. 1 is not obtainable, or in cases where a second grade oil will serve every purpose, as in temporary work. In the same re-drawing of specifications the character of the coal tar from which creosote may be derived was more definitely stated. It is unnecessary to quote or copy these specifications because they are available and well known, and the specific points regarding creosote standards belong to a discussion of the subject from the chemical standpoint.

Several additional problems relating to the use of creosote as a preservative are pressing for solution. These include the advisability of using various mixtures of creosote and other products such as filtered tar, water gas oil, or the combining of creosotes of different grades; the use of water gas creosote either alone or in combination with pure coal tar creosote; the value and possible use of oil from coke over tar; and the combined use of creosote and crude oil. Another problem is that of developing methods by which adulterants may be more readily detected both in a commercial and laboratory analysis, or at least, a standard method suitable for general use.

Much remains to be done in the way of setting more definite standards both for processes and preservatives. The United States is fortunate in having a Government laboratory at Madison, Wis., where a large amount of most excellent experimental work is under way, and from which definite results of very great value to the industry have already been procured. In addition to this there is a large number of individual and corporation investigators throughout the country, and it may be expected that before many years much of the confusion arising from different specifications and standards will be done away with.

The mechanical equipment of the modern American plant leaves little to be desired. High pressure cylinders six or seven feet in diameter and up to 150 feet long are practically the standard. Labor saving devices are in much more general use than in Europe, and hand work is reduced to a minimum. One of the important recent improvements is an arrangement whereby the measuring and working tanks are mounted on scales, so that the amount of creosote or other solution absorbed is measured closely by actual weight rather than by volumetric scale readings. Automatic devices for unloading full tram carloads, and machines which adz, bore saw to even length and stamp with the date, ties before treatment, are included among the mechanical developments.

The present status of the wood preserving industry in America is the result of a normal growth, which during late years, has been very rapid. Much of the educational work has been done, and nearly all large wood consuming corporations now readily accept preservative treatment not only as a matter of economy but of necessity. The present tendencies seem to be toward co-operation and greater harmony between the many interests involved. The air of secrecy which formerly shrouded the operation of many plants has largely disappeared, and more open discussions and frank statements regarding the work are apparent. The American Wood Preservers' Association, with a large and rapidly increasing membership, is doing much toward bringing together the various interests and securing greater co-operation. The railroads, which have been the pioneers in preservative work, have for many years investigated and reported upon the subject to the American Railway Engineering and other railroad associations. More recently the lumbermen, through their interest in the production of material for treatment, are taking an active interest in wood preserving matters. As a means of disposing of inferior products and broadening the market for all forms of wood material, preservative treatment occupies a very important place. The start has already been made by some western lumber companies in building and operating plants of their own.

Wood preservation has a very far reaching effect on the conservation of our national forest resources. At present it is one of the strongest factors in the reduction of our annual timber bill, which including lumber and wood in all forms, reaches an enormous total equivalent to at least one hundred billion board feet, worth over one and a quarter billion dollars at point of manufacture. Preservative treatment reduced the drain on the forests by increasing the life of timber so that the consumption is greatly lessened. Not only this, but it permits the use of many inferior woods which would be useless without treatment. As a striking example, the eastern railroads had largely exhausted the supply of durable white oak and cedar cross ties adjacent to their lines. White oak and long leaf pine when shipped long distances, became very expensive and the railroads were almost forced to develop other sources of supply. Most of the cheaper woods still available locally, were non-durable species, such as beech, maple, sap pine, etc., and it was only upon the adoption of preservative treatment that these woods could be utilized and the local cross tie supply of treatable woods drawn upon. Owing to the comparatively low freight rates on ties shipped from southern ports, pine will continue to be used by the northeastern railroads which have rail connections on tidewater. While long leaf pine ties under rigid heart specifications have become expensive, treatment will permit the acceptance of long leaf with more sap wood. This class of ties costs less, is hard enough to wear well if laid with tie plates, and serves to augment the local supplies of broad leaved woods.

Aside from this application the treatment makes possible a change in the character of construction timber used.

For example, long leaf pine has become practically a standard in wood bridge and trestle construction and when used untreated it was necessary to have expensive heart pine which resisted decay. By creosoting or other forms of treatment it is now possible to use timber with a larger percentage of sap, and therefore cheaper and more readily obtainable. Since decay is prevented the preserved timber does not suffer loss in strength for many years, thus permitting the use of a lower initial factor of safety.

It is very difficult to estimate for the country as a whole the saving from the use of treated material, because of the great variety and complex character of the timber used. Forest Service Bulletin No. 78, however, approximates the saving in a statement that "nearly two billion feet board measure of structural timber are destroyed each year in the United States. . . . If all the timber were treated which it is practicable to treat and which could be treated at a profit, nearly six billion feet board measure or sixty per cent would be saved. This saving would represent the annual growth on twenty million acres of well-stocked timberland." In cross ties alone the Government estimates that proper preservative treatment would reduce the annual cut to the extent of nearly sixty million ties per year, which is equivalent to two billion board feet.

The present tendencies in the character of treatment are toward lighter impregnation with creosote, except in marine work and construction timber, or the use of mixtures which reduce the initial cost. No less than sixteen of the plants listed by the American Wood Preservers' Association use a light impregnation creosote process and probably as many more use it on at least part of their material; while several more plants use zinc chloride and creosote in mixture. This means that a large percentage of the treated cross ties used by the railroads have less than six pounds of oil per cubic foot. Actually they have more than six pounds in the treatable or sap portion of the ties because the absorption is figured on the gross cubic contents. It may be argued that these light treatments are poor economy in the long run, and it is indisputable that they have not had the test of time. It must be remembered, however, that wear under the rail is responsible for a large percentage of tie failures after five years and that full impregnation would certainly not be justified without large and expensive tie plates and screw spikes. Recent developments in the adzing and boring of ties before treatment promise a solution of the question of mechanical wear in relation to impregnation and decay.

Apart from the many details which are in a fair way of being worked out, there are two very broad problems which confront the wood preservers of America, and to which they should give their attention if the industry is to remain permanent and profitable. One of these is the source of supply for creosote oil, the present indications being that a shortage is imminent and that high prices will prevail. While the consumers can perhaps do little of themselves to stimulate pro-

[1] May be considered as still in the experimental state.

duction, they can at least co-operate with the manufacturers and encourage the construction of by-product ovens in America, and maintain trade relations which will guarantee to the European distillers a definite market for their available creosote. Enough creosote is burned in the bee hive coke ovens of the United States every year to supply all reasonable demands for years to come.

The other problem is that of timber supply and it is one to which the wood preservers have paid too little attention. This applies to the owners of commercial plants, and particularly to the large railroad companies which either operate their own treating plants or have their work done by contract. At the present rate of increase, the cost of treatable cross ties and other material will, in a very short time, be equal to that of white oak and other more durable woods. There are still enormous supplies of cheap woods available, and it is for this very reason that steps should be taken to perpetuate the supply. In some regions, however, the supply of treatable timber is already becoming depleted, and many plants will have to seek new locations or have their material shipped long distances within the next ten or twenty years.

Most of the hardwood timber, suitable for treatment, is of such slow growth that under present conditions it would not be profitable to reproduce it under any system of forest arrangement. In the South, on the other hand, are several fast growing trees which would respond very readily to a system of conservative management. In the loblolly pine belt, for example, the output of timber from a definite area could easily be made permanent. It is estimated that about one hundred thousand acres of well stocked loblolly pine land would produce 1,000,000 ties per annum for all time. It would have been very easy at the time some of the first railroad plants were built to have acquired timber lands at comparatively low cost and by proper management made them a permanent source of cross tie supply. This has not been done.

The railroads and other wood consumers are even now facing a distinct timber supply problem. Broadly considered, a treating plant should have back of it a definite source of timber supply, since as long as it depends on the local producers or on the middlemen for the timber used, fluctuating prices will prevail and there will be no assurance that the investment will be permanent.

The Liquid Air Industry

At First a Curiosity, Now a Commercial Product With Varied Uses

So vast has been the commercial development of the refrigerating industries, and so numerous are the applications of cold to meet the needs of modern civilization, that the "Congress of Refrigeration" which met a few weeks ago at Toulouse found many matters of general importance to consider.

One of the weightiest of these was the definition of the new units of measurement and terms of appellation required in such industries.

The most essential of these terms and units is the *frigorie*, which will doubtless come into general use from its simplicity and convenience.

The *calorie*, the heat unit, signifies the amount of heat required to raise 1 kilogramme of water from 0 deg. Cent. to 1 deg. Cent.; the *frigorie* is the exact inverse, i. e., 1 kilogramme of ice at 0 deg. Cent. will furnish 80 *frigories* in melting, in other words it will abstract 80 *calories* from the surrounding medium.

Among the refrigerating industries there is none more interesting than that of the manufacture and application of liquid air, and the most marked advance has been made in this line in the recent past. The subject is discussed at length by Dr. Charles Nordmann in one section of his article on the "Application of Cold" in the *Revue des deux Mondes* (February 1st).

He pays homage especially to the achievements in this line of the young French scientist, Georges Claude, "whose merit consists especially in having rendered *industrial*, i. e., simple and economical, what was merely a difficult laboratory experiment." Thanks to the ingenious processes devised by him liquid air is produced in quantities which may be estimated in hectoliters instead of in scanty ounces. Curiously enough, as Dr. Nordmann remarks, the chief item of expense in the production of great cold is the cost of fuel! This is because the immense pressure demanded by the process must be secured by some form of steam-power, unless, of course, water-power is available.

Dr. Nordmann queries: "Why is the manufacture of liquid air so important and what purposes does it serve?" and answers himself as follows:

"In the first place it permits the simple realization of the long-sought means of separating the air into its two elements, oxygen and nitrogen, whose production in a pure state is one of the principal problems of industry.

"This separation is made in a manner analogous to that of the rectification of alcohol, by *fractional* distillation. . . . . Oxygen which boils at −182.5 deg. Cent. is less volatile than nitrogen, which boils at −193.5 deg. Cent. This difference, infinitely precious, permits their separation. If liquid air is allowed to evaporate freely the nitrogen will escape in larger proportions than the oxygen until the residual liquid will finally be composed of almost pure oxygen. But this process is not economical, since it demands a large quantity of liquid air to yield a small quantity of oxygen.

"M. Claude escapes this difficulty by liquefying the air, not in a single 'block,' but progressively, in such manner as to have at first an excess of liquid oxygen, and then an excess of liquid nitrogen. The latter, circulating in a rectifying column like that of distillers, subsequently condenses only the oxygen which rises in this column; this condensed oxygen flows toward the bottom, while the nitrogen escapes at the top. Thus we succeed in producing very cheaply pure oxygen and nitrogen from the most wide-spread and abundant of raw materials, atmospheric air.

"The employment of the former is of the first importance in industry because the combustion of bodies, i. e., their combination with oxygen, is the origin of nearly all the energy we use in our machines.

"But when combustibles are burned in air, not only is the combustion less active than in pure oxygen, since four fifths of the air consists of the inert nitrogen, but above all this inert nitrogen absorbs ineffectually a great part of the heat produced in bringing its temperature up to that of the surrounding vicinity.

"This is why iron, which will not burn in air, will burn in oxygen, and why the oxyhydrogen blowpipe will bring to a lively incandescence the chalk which scarcely reddens in the flame of hydrogen burning in air.

. . . . "Metallurgy has begun to utilize the new resources of pure oxygen with which liquid air provides it. Among the most astonishing applications of this new industry we must cite also the autogenous welding of metals, whose uses are numberless, and which is capable of realization because of the high temperatures obtained by the combustion of pure oxygen with gas, acetylene, or petroleum.

"Lastly, there is the cutting of metals, which employs in an unexpected fashion the property just cited, by which iron heated to redness burns with violence in oxygen. Thus, if a piece of steel . . . be brought to a 'white-red' heat at one point and a jet of oxygen be directed against this point, the combination of the iron and the oxygen will be effected with such violence that the metal will be cut, whatever its thickness. A tiny jet of oxygen has thus been seen to cut instantly plates of a thickness of 35 centimeters.

"Liquid oxygen also permits the construction of explosives of extraordinary violence. At the demand of the Minister of War MM. d'Arsonval and Claude recently made experiments with powdered aluminium immersed in liquid oxygen and touched off by a capsule of fulminate. This new explosive proved to have a destructive force equal to twice its weight of powder. . . . . Moreover it produces no noxious product of combustion, only alumina remaining. It has the inconvenience, which may at times be an advantage, that it must be prepared at the moment of use. . . . The explosive liquid oxygen—carbon—which, however, disengages the poisonous carbon monoxide, has shown itself to be equally remarkable, and almost as powerful as dynamite.

. . . . "Nor is pure nitrogen without applications: we know the enormous importance of the problem of fixing the nitrogen of the air in the form of ammoniacal or nitrogenous fertilizers. But by passing nitrogen over calcium carbide at a red heat we obtain very simply one of these fertilizers, cyanimide. But the nitrogen must be *very pure*."

Thus, to summarize Dr. Nordmann, the fractional distillation of liquid airs offers a new solution of one of the most important problems of agriculture, as is proved by the number of cynanide works employing liquid air which have sprung up in Europe.

But air also contains argon, neon, krypton, xenon, and metargon; and in spite of their great dilution they can be extracted in a pure state in considerable quantities by means of fractional distillation.

"M. Claude has discovered that one of these, *neon*, so rare that there is only 1 liter in 65,000 liters of air, has the singular property of being traversed with exceptional and extraordinary facility by an electric discharge. where 1,000 volts are required in the case of air, 13 volts will suffice for neon. Hence neon tubes, . . . whose calm and beautiful red light may now be admired by Parisians in many places, offers a new and elegant solution of the problem of economic lighting.

"In the fabrication of these tubes a little difficulty arose which gave M. Claude the opportunity of applying another very curious property of low temperatures. . . . . The magnificent luminescence of neon is easily masked by the presence of infinitesimal traces of strange gas, so that even in a luminescent tube containing absolutely pure neon the vivid brilliance which first appears diminishes in a moment to almost nothing because of the minute impurities disengaged from the electrodes by the passage of the current. Hence it was necessary to find a means of completely absorbing these impurities until the electrodes ceased to give them off. Success was obtained by utilizing the remarkable property, discovered by Prof. Dewar of London, which charcoal possesses, of absorbing gases with extreme energy when it is cooled to the temperature of liquid air. But the more easily liquefiable the gases are, the greater the facility with which they are thus absorbed by the carbon.

"During their formation the neon tubes are furnished with lateral *tubulures* which inclose charcoal and are immersed in liquid air, and which are separated by the blowpipe when the operation is terminated. The charcoal entirely absorbs the impurities disengaged and leaves the neon slightly liquefiable.

"To give an idea of this astonishing pneumatic property of charcoal cooled in liquid air, it suffices to say that by this process there can be obtained, in a few minutes, a reduction of an initial pressure of one 1/1,000 in a Crookes tube to a pressure of 1/10,000,000 of an atmosphere.

"This curious phenomenon is now employed on a huge scale for the obtaining of high degrees of vacuum for industrial or laboratory uses."

Radio-active Manures

M. Marcel Vacher, Member of the "Conseil Supérieu" of Agriculture, at the last meeting of the National Society of Agriculture communicated the really extraordinary results obtained recently in France at the School of Agriculture of Berthonval, as well as in England at the Agricultural College of Newport, by the employment of certain radio-active manures.

By his studies of the effects of uranium on germination, M. Daniel Berthelot had opened the way. MM. G. Petit, Professor at Alfort, and B. Ancelin, agricultural engineer, undertook some new experiments on March 14th last, and this time using radio-active water and ordinary water for the germination of two distinct groups of seeds of Indian corn. At the end of eleven days the seeds of both groups were germinating; but while the radicles of the group treated by ordinary water were not more than 19 centimeters in length, the radicles of the group treated by radio-active water reached 94 centimeters in length.

At Berthonval and at Newport the radio-active manures have given results not less surprising.

At Berthonval the amount of oats produced per hectare (about 2½ acres) was with ordinary manures 3,400 kilogrammes, whereas with radio-active manures it was 3,910 kilogrammes; the produce of sugar beetroots was 19,400 kilogrammes with ordinary manures, and 22,200 kilogrammes with radio-active manures. That is to say, a difference to the profit of radio-active manures of 510 kilogrammes in the first case, and of 2,800 kilogrammes in the second.

Elsewhere the energetic action of radio-activity has been remarked on the vegetation of chrysanthemums, roses, geraniums, and cannas, this action producing a more regular and precocious flowering, and a far brighter coloring of the flowers.

All that seems to promise a new future for agriculture and for horticulture, and is a new process due to the admirable discoveries of M. and Mdme. Curie, of M. Henri Becquerel, and of M. Jean Becquerel, in pursuing such interesting studies on the effects of radium.—*Chemical News.*

London's Auto Busses.—It appears that the use of the auto bus in London has grown to such an extent within the recent period that the municipal authorities are beginning to be alarmed about it, and it is now decided that the number to be allowed in the city must not exceed 3,000 and no more than this will be permitted. At the present time there are somewhat over 2,000 auto busses running in the city.

Charles Proteus Steinmetz

One Man's Share in a Few Record Years of Electrical Progress

By Douglas Sutherland Martin

THE history of the world is read in the lives of the world's Great Men. The history of each country is recorded in the lives of the men who have discovered it, settled it, developed its resources, built its bridges, and governed its people. The history of each industry is clearly recited to us as we study the daily life and achievement of the men who have helped to build it up, either by way of invention, or by financing, or by directing the workings of the millions of operatives. All that man wants to know of the growth of the electrical industry can be learned from a study of the doings of the few great men which that industry has produced.

In an industry which has been built up, virtually within a single generation, to a point which to-day represents a capitalization of at least ten billions of dollars, relatively few have acquired great wealth; and in a science which has been carried forward and applied to economic needs at a far more rapid rate than any other in modern times, relatively few stand out as Great Men, either as experimenters, inventors, scientists, mathematicians, engineers, teachers or writers. The subject of this short sketch—Charles Proteus Steinmetz—is conspicuously one of these few; and in him we seem to find, to an altogether extraordinary degree, a combination of qualities which would have insured greatness for him in practically any one of those directions which I have named. Greatness is relative. Judged by the only human standards which we know, Steinmetz, mentally and intellectually, seems to the average engineer almost Super-Man. If we could write a history of the last ten years of Steinmetz's life, and reduce it to simple terms, we could give to the average citizen at least some of the hard facts which are the reasons for the well-lighted streets, the cheap car-rides, and the quick elevator service which he is to-day enjoying in the pursuit of his business or his pleasure.

Steinmetz made himself famous, so far as electrical men were concerned, by a masterly paper before the American Institute of Electrical Engineers away back in 1891–2. That paper dealt with a subject upon which nearly every one at the time was pretty meagerly informed. It was not written in brilliant English; and many of its 200 pages were filled with mathematical signs and an advanced reasoning which put the whole work on a plane considerably above the head of the average electrical engineer of the day. But from it all emerged a fact and a law—a fundamental Law of Magnetism. Steinmetz found an exponent connecting the magnetization with the hysteresis loss; or, in plain English, he gave to the designers a method by which, when they had figured how much magnetizing *current* they were going to use in order to magnetize a piece of iron in an electrical generator or motor, and thereby cause that iron to throw out so many lines of magnetic *flux*, they could at once figure how many *watts of loss* there was going to be in the iron, and therefore *how hot* it was going to be when worked under given conditions in practice.

That alone should make a man famous: because it was nearly all pure pioneering; was based on work which had to be carried out with—as it seems to us—the crudest possible power plant and measuring outfit; and because it furnished results which were of immediate commercial importance. You buy and wear a collar or a shirt or a suit of clothes without thinking at all of electricity; but you will find that, in designing the motors which ran the machine in the factory and the spindle in the mill, the man with the slide-rule used the Steinmetz law, directly or indirectly, when he figured the amount of iron which he would put into his motor. The designer does not think very frequently of the name of the particular genius who furnished him with his data. Certainly the wearer of the collar knows nothing about the matter. But it is things like this which must be borne in mind when we hear or read that Steinmetz is a great man, and that he has done things which have been productive of great results in many and scattered directions.

That investigation into the phenomena of the magnetic circuit, and the discovery of the 1.6 Law, was one of the most valuable things which Steinmetz has ever done; but it is quite impossible accurately to appraise its value, or to declare that it has been of greater moment to the industry and to the community than his later work on, say, the induction motor, on the mercury arc rectifier, or on the beautiful magnetite arc lamp. His is a many-sided genius, which has found scope for the exercise of its manifold powers in a variety of directions, many of them concerned, in one way or another, with the utilization of electrical energy. But it would seem that the greatest gains to the industry have resulted from the altogether remarkable study which he has made of the engineering of high-voltage power transmission—a study which has not only placed at the disposal of the industry a solution of many of its most perplexing high-voltage problems; but has, in addition, provided it with a wonderfully clear understanding of the directions in which the attack of the militant engineering body must be directed.

Utterly lacking in all the vanities of the self-styled leader, gifted at once with the cool head of an engineer and the bold imagination of an artist, concerned only with the achievement of results in the direction which, to him as to the other great electrical engineers of the day, is the direction of true progress, Steinmetz has attained a position of eminence in the regard of electrical men—hard-headed, practical men of affairs—which is really not far removed from the standing of an Oracle. He has foreseen and has directed progress. He has foreseen; and his vision has shown him that the path which must be followed is the path leading to the bulk-supply

Charles Proteus Steinmetz.

of electrical energy. In his future state a nation-wide programme of conservation will be carried out. Generating plants in villages and small cities will be superseded by substation service from great trunk supply lines. A few main stations of great capacity will furnish all the power requirements of a given vast area, and will be built for the highest practicable operating pressures—say 150,000 to 200,000 volts. This is not mere visioning. Much of the ground has already been made; and to Steinmetz, more than to any other man living, are we indebted for the achievement.

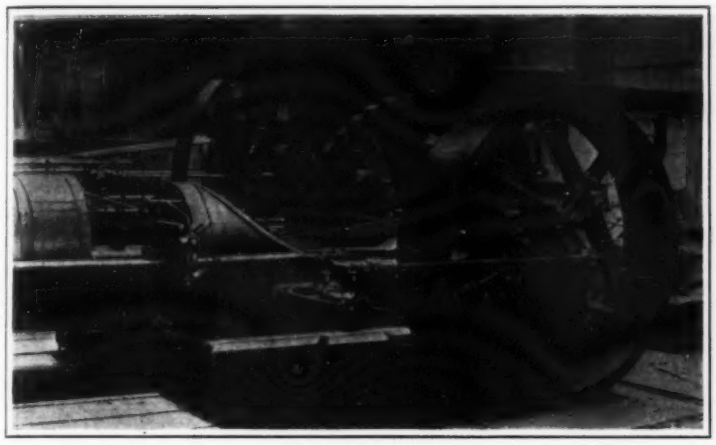
It seems a ridiculously short time since engineers were talking of the distant day when transmission pressures of 100,000 volts and more would be a commercial possibility. Now they are a commercial commonplace. It is likely that Steinmetz has done his greatest work in this field. He has brought the subject down from the vague mists of the upper air, and has reduced it to the terms of a fairly exact science. Engineers at one time, for instance, thought they were limited by corona loss: they knew that at high voltages there was a dissipation of energy from the current-carrying conductors into the surrounding air. Steinmetz addressed himself to the matter—and now we know a good deal of the nature of corona. We can predict with certainty the critical value of the line voltage at which it is going to start; we can calculate the amount of loss there will be under given conditions of spacing, altitude, humidity, and so on; and we can proceed to design our lines and adopt our voltages accordingly, and work out schemes for the raising of the critical corona pressure. Much honor to the men who have worked out the details, carried out the tests, and established their fundamental laws: Steinmetz pointed them the way, and showed them, step by step, how far they had traveled, whither they must proceed, and what pitfalls they must avoid.

Or, again, engineers knew of dreaded disturbances in the line—sometimes vaguely termed "static" or again "high frequency" effects; of destructive surges—not necessarily attributable to any lightning stroke—which coursed up and down the line; sometimes spilling over the insulators and short-circuiting miles of line to the ground; sometimes entering the substations and power stations, and traveling to the heart of generators and transformers and ripping the life out of the apparatus. Steinmetz delved deep into a study of the problem, and in course of time began to deliver a masterly series of papers on the electric "transient"—an abnormal something in the system, of transitory nature, sometimes destructive, always potentially dangerous. Now we know a good deal of what these transients are, how they are set up, the different forms which they may take, the line constants on which their value depends. Now also station engineers can lay out their equipment so that, by no switching connections which they may employ, will they ever wittingly set up one of these high-voltage or high-frequency disturbances in their system. It can only be stated in the briefest manner here that the subject is one of the very greatest intricacy. It is still in a highly involved condition, and there are an infinity of outstanding problems. But the point is that we have now reached the stage where there are definite problems on which to work. The preliminary study, the work which has shown us something of the nature of these destructive disturbances, the wrecking-power of lightning, the life-like imitation of lightning which may be produced any day anywhere by an accidental condition in the line, or by the violation of certain rules—this work is the work of genius. There will be no public recognition of it; and, even among the engineers, the full meed of gratitude and appreciation will only be extended to the pioneer by those who have come into the most intimate contact with the technique of the matter. But this work alone has made high-voltage operation a possibility.

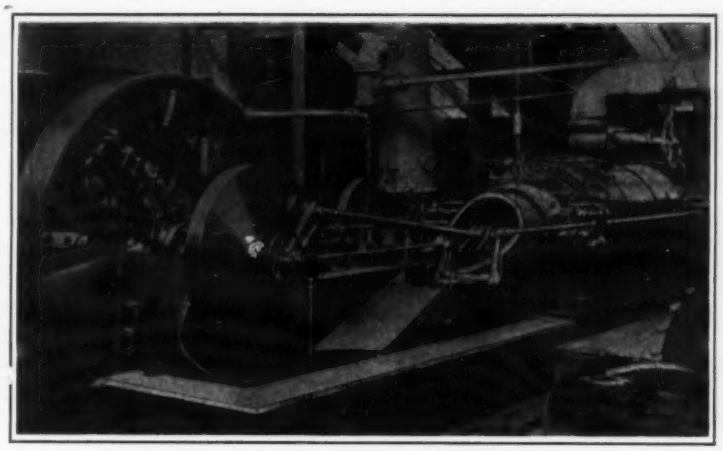
Possibly an even more remarkable greatness resides in Steinmetz's unique power as a teacher. He could not have been the great teacher that he is if he had not possessed the genius for himself performing the pioneer work. But he would have been materially less of a national asset if he had lacked his great powers of exposition—an appreciation of the limitations of his audience or his readers, an understanding of the psychology of teaching, and a wonderful literary style. However well he might himself have understood, say, the genesis of a traveling wave in a 200-mile transmission line, the economic value of much of his knowledge might have been lost but for this priceless gift of exposition. Few among the great men of science, dealing with theories of even half the intricacy of those in which Steinmetz delights, have ever possessed his command of the English language—a possession which enables him always to use the right word in the right place, the parenthesis without which the beginner might just miss a shade of his meaning, the idiom where the idiom alone can explain, the analogy where it is most apt. These powers are brought into play before audiences of widely varying character. Steinmetz is perpetually lecturing, scattering the good seed with lavish hand from his own rich storehouse, to the Institute of Electrical Engineers or one of the sister societies, to the traveling salesman of the manufacturing company, to the undergraduates of the University who come to his Chair; reducing to a few simple and easily-remembered sentences the result of months of laborious study, whether it be on the hunting of synchronous machinery, the evils of high-tension switching, the insulation of a transformer, the handling of a destructive short-circuit, or any one of a hundred other problems.

He has looked ahead. He has studied. He understands. More important still: he has made the other man understand. Therein, I think, lies the secret of his greatness.

An English syndicate has acquired for $71,400 the patent rights for England and the colonies (not Canada) for the manufacture of yarns and cloth made of nettle fiber. The German company, with works in Schleswig-Holstein, will shortly begin actual working, and it is understood that they will specialize in the manufacture of yarns suitable for carpet manufacture.—*Chemical Engineer.*



High-pressure engine.



Low-pressure engine.

The Shuman-Haines Steam Engine*

A Low Pressure Engine Originally Designed for Solar Power

In engineering, whatever it may be in other branches of applied science, discovery and progress is rarely nowadays a matter of fortuity. Patient elaboration of detail coupled with sound experimental research work has accounted for nearly every real step in advance, great or small, which has been made within recent times. Nevertheless, many important inventions have had strange origins, and very frequently represent the development of some offshoot of the parent idea. The de Laval steam turbine, for instance, was originally evolved as an accessory to a cream separator. The Diesel engine was developed more or less as a by-product of its inventor's endeavor to apply the Carnot cycle to practice. And so on throughout a long chapter.

To the list of inventions which have originated in this manner we have now to add another, the Shuman-Haines steam engine. Our readers will, no doubt, recall our descriptions of the Shuman sun-power plant in the Scientific American of January 25th, 1913. The steam generated in the apparatus is kept low in pressure. Its temperature, in fact, barely exceeds 212 deg. Fahr., so that some low pressure form of engine has to be used in conjunction with the plant. The exhaust steam turbine was naturally the first form of low pressure prime mover to suggest itself for the purpose. But the economy of such turbines rapidly decreases as the size of the plant becomes smaller, and for moderate powers, say, below 500 horse-power, their steam consumption is excessive in comparison with that of larger powered units. Mr. Shuman's first sun-power plant had a maximum horse-power of 32; his second, erected at Meadi, near Cairo, has a maximum of about 29. The problem on which the success or failure of the sun-power plant hung was, thus, the devising of an efficient small powered steam engine using atmospheric steam. In conjunction with Mr. E. P. Haines, of Philadelphia, Mr. Shuman set to work, and in the end succeeded in producing a low-pressure reciprocating steam engine adapted to his needs.

At this stage the matter might very well have rested. But Mr. Shuman and his colleague recognized that the low-pressure engine which they had constructed was by itself capable of being separately developed, and that apart from its primary duty as a sun-power plant engine it had a distinct field of its own in general motive power work. The very reason which made it necessary to design and construct the engine gave it a field for employment. No small powered exhaust steam turbine had been developed. Hence, the use of the exhaust steam from a high pressure reciprocating engine in a low-pressure turbine was only practicable when large powers were in question. The Shuman-Haines engine, therefore, promised to do for the small powered reciprocating engine what the exhaust steam turbine did for the large powered engine. Arguing thus, the inventors again concentrated their attention on the engine, and quite apart from its sun-power aspect developed it along lines which would make it suitable to the general power user. Incidentally, they realized that their engine not only would score over the exhaust steam turbine when small powers were involved, but that its slow speed gave it additional advantage. The higher speeded turbine was restricted practically to the generation of electricity. Their own slower speed engine could be applied directly to the mechanical driving of, say, a line shaft or a pump.

A second line of development also suggested itself. The economy obtained with the early low-pressure engine, referred to above, was solely traceable to the combined effects of certain modifications and improvements of construction which had been adopted. If, therefore, these modifications and improvements were applied in the case of a high-pressure engine, a similar economy, it was argued, would probably result.

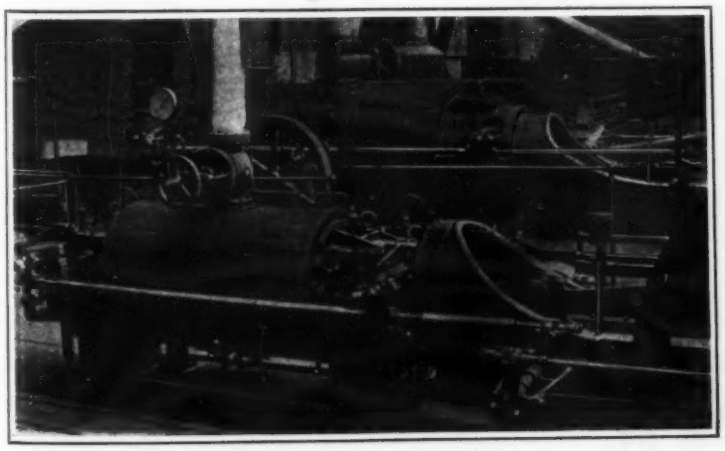
After the design of the earlier engine had been carefully reconsidered and amended in several important respects, an order was placed for one high-pressure and one low-pressure engine with Fraser & Chamlers, Limited, of Erith, Kent. Both these engines have now been completed and tested.

In all essential details the high-pressure and the low-pressure engines are practically identical. Indeed, the drawings for the one would, merely with the scale altered, serve very well for the other. The line engravings accompanying this article are reproduced from the drawings of the high-pressure engine.

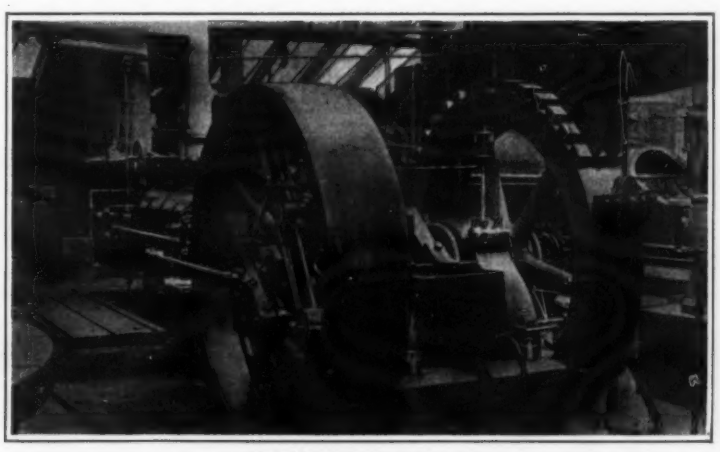
The engines in outward appearance are not very different from an ordinary single-cylinder horizontal steam engine, except insofar as the lengths of their cylinders strike one as being out of proportion. Closer examination, however, shows that in the details of construction there is much originality. Indeed, it was by taking each source of loss in a steam engine separately and working at it until an improvement was effected that the inventors have produced their interesting engine. For the time being we will confine our attention to the high-pressure engine.

The chief ends aimed at by the designers were the reduction of losses due to friction, valve and piston leakage, initial condensation and clearance. By considering each of these items separately we will obtain a good idea of the principal features of the engine. First, as regards friction. One of the greatest sources of loss from this cause ordinarily lies in the piston rod stuffing-box. How great this may be can be judged from the fact that quite a large engine can be pulled up by the undue tightening of the gland studs. In the Shuman-Haines engine the piston rod gland is an adaptation of a gland devised some few years ago by Mr. Haines for the intermediate packing of a tandem gas engine. The details of its construction may be gathered from Fig. 1. We need only say that it is of the metallic floating type, and is provided with an oil seal. In an ordinary steam engine an equally important source of frictional loss is to be found in the slide valve controlling the admission and exhaust of the steam. In the engine under notice this loss is avoided or greatly reduced by employing separate valves for the admission and exhaust and by the peculiar construction of these valves. The exhaust valves, as will be gathered from Fig. 2, are of the mushroom type, and are disposed in the end covers of the cylinder. There are six of these valves at each end. The mechanism operating them will be described later, but at present we may say that it introduces very little friction. The admission valves are particularly

* Reproduced from *The Engineer*.



High and low-pressure engines.



High-pressure engine.

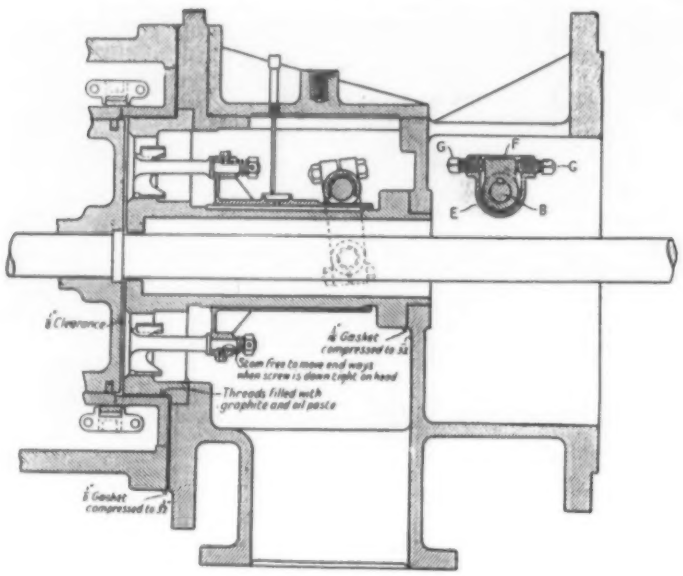


Fig. 1.—Exhaust valves.

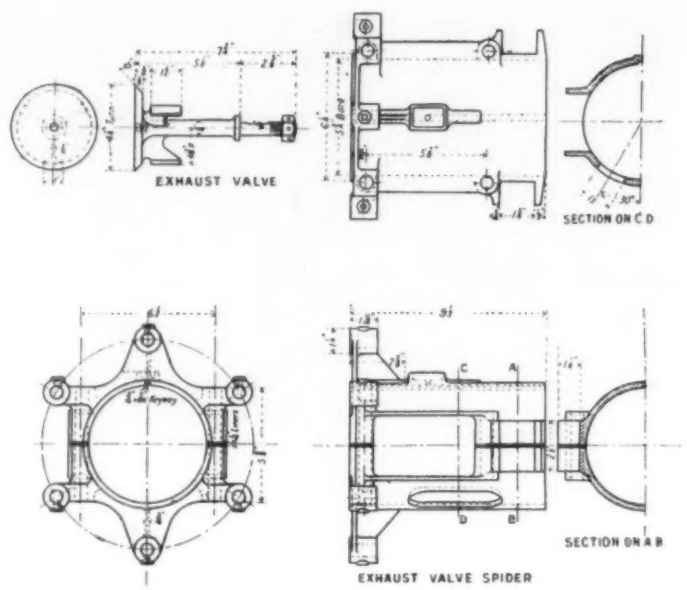


Fig. 2.—Exhaust valve and spider.

interesting. The inlet ports, as will be seen from the longitudinal section of the cylinder Fig. 4, are very narrow, and are disposed as close as possible to the end covers. In Fig. 5 a cross section of the cylinder in the plane of these ports is given, and from this it will be understood that at each end of the cylinder there are eight admission ports extending right round the circumference and separated only by narrow bridge pieces. The admission valve (see Fig. 5) is in the form of a ring divided into four quadrants. A continuous ring of slightly greater diameter circumscribes the quadrants. Two small laminated springs attached to the outer ring press against the back of each quadrant. The outer ring is reciprocated by means of the valve gear described below, and the quadrants are compelled to follow this motion since they are embraced on each side by small lugs depending from the outer ring.

The next source of loss to be considered is the leakage of steam past the valves and piston. From the description of the valves given above it will be seen that their construction insures steam tightness to a degree hardly attainable with ordinary flat dee-slide valves. With the latter type of valve, it has been shown by Nicolson and Calendar, a very serious loss may occur by the leakage of steam from the steam chest straight through into the exhaust pipe. Their figures have been challenged, but that some loss, and on occasions a serious loss, does take place is well known. In the Shuman-Haines engine any steam which may leak past the admission valve goes into the cylinder where, for the better part of the stroke at least, it would be usefully employed and would not escape direct to the exhaust. As regards leakage past the exhaust valves it will be noticed from Fig. 1 that each valve is permitted to take a good seating in the end cover by being given a certain amount of endwise flexibility through the agency of a spring on its stem. Then, as regards piston leakage, Fig. 4 shows that a double piston is employed, and that each piston head carries three rings. The chief reason for the adoption of this construction will be mentioned shortly, but it will be understood that it incidentally prevents leakage, since the steam is given twice the usual amount of packing to circumvent.

Next, as regards initial condensation. The separation of the passages by which the hot high-pressure steam enters the cylinder, and by which the cold exhaust steam leaves it, is one of the means adopted to prevent the loss due to this cause. Then from Fig. 4 it will be noticed that the cylinder for its full length is provided with a steam jacket. This jacket is fed with live steam, and, in fact, forms the steam chest for the cylinder. It is equally important to prevent as far as possible the conduction of heat through the end covers.

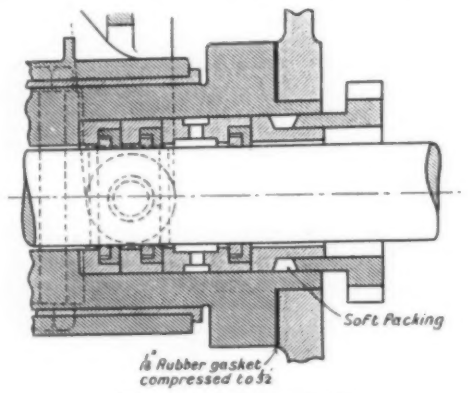


Fig. 3.—Piston-rod gland.

This condition is secured, in the low-pressure engine only, by fitting over the inner faces of the end covers iron sheets on to which rubber has been vulcanized. The valve faces are also treated in this manner. The adoption of the double piston is a further preventive against condensation. In the first place, it virtually amounts to steam jacketing the pistons, since some steam is always certain to leak through into the space between the pistons. Secondly, each half of the cylinder volume has to deal only with the steam from its own ports. Thirdly, the efficacy of the steam jacket round the walls is multipled by two. This point perhaps deserves some discussion. The argument, it will be understood, is simply that the steam at each end of the cylinder has practically a steam jacket to itself. In a single pistoned cylinder the steam in the jacket is drained of its heat by the alternate expansion of the steam on both sides of the piston. In the Shuman-Haines engine this is also true, but the area of the surface through which the heat is allowed to pass is twice as great for the same volume of working steam. At first sight there appears to be a debit side to the arrangement, as well as a credit side, namely, that the jacketing of the steam leaking through into the space between the pistons is so much wasted effort, since this steam takes no part in the development of motive power. This argument is not sound, because the maintenance of high temperature steam between the pistons is, as we have said above, equivalent to their being steam jacketed, and prevents condensation taking place on their faces. Further, this high temperature steam may be said to play the part of an internal steam jacket, always moving along the cylinder walls just in front of the expanding working steam. It is clear, therefore, that whatever heat is added by the external jacket to the steam between the pistons is not lost, but is employed probably just as efficaciously as it would be if it were passed through the walls directly in contact with the working steam.

The last source of loss on our list is "clearance." Inspection of Fig. 4 shows that the inventors of this engine have done practically everything possible to reduce the clearance volume. The faces of the pistons are plane, the exhaust valves are flush in the end covers, the admission ports are very short, and the piston comes to rest within ⅛ inch of the end cover. In the high-pressure engine the clearance volume is 0.91 per cent of the working cylinder volume; in the low-pressure engine it is even less, being only 0.64 per cent.

All the sources of loss with which we have been dealing are, of course, quite well recognized by most engineers, and the methods by which the inventors of this engine have overcome or reduced their effects are not novel in principle. Nevertheless, credit is due to them for the manner in which they have combined the several objects aimed at, and for the mechanical details whereby they have realized their aims.

We will now fill in the details of the engines not covered in the above. First, as to the cylinder construction. The cylinder proper is (see Fig. 4) a plain flanged barrel slightly bell-mouthed in-

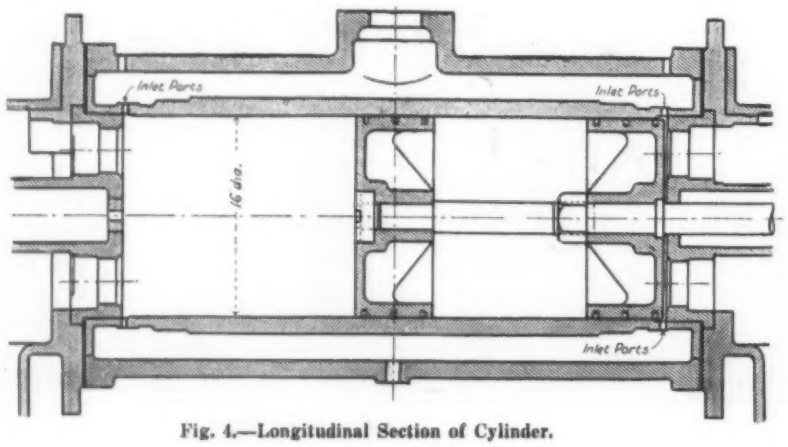


Fig. 4.—Longitudinal Section of Cylinder.

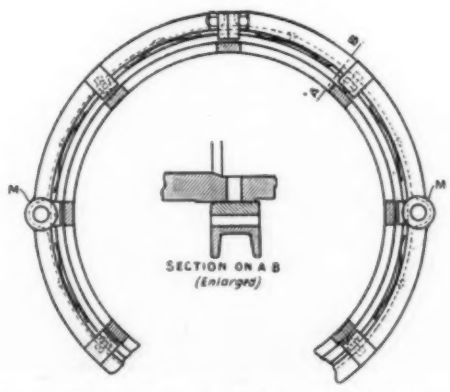


Fig. 5.—Cross section of cylinder and admission valve.

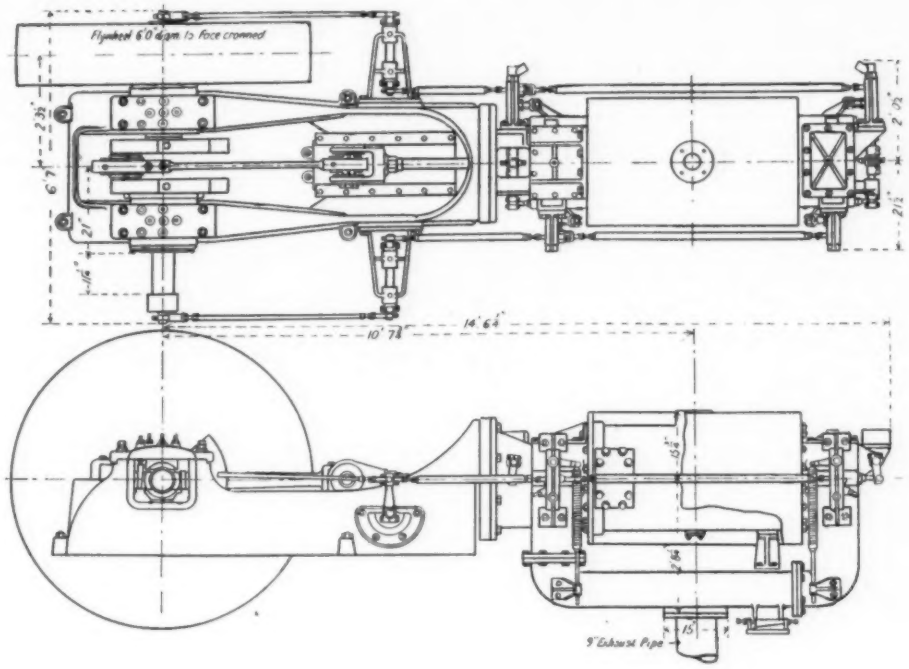


Fig. 6.—Plan and elevation of Shuman-Haines engine.

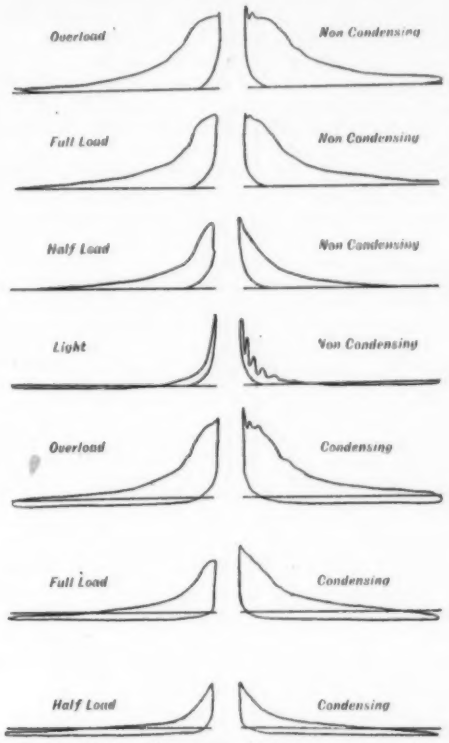


Fig. 7.—Indicator diagrams—high-pressure engine.

ternally at each end, and provided externally with faces for the admission valve rings. This barrel fits inside another, the annular space thus formed being utilized as the steam jacket. The external barrel midway along its top has a seating on which is carried the live-steam stop valve. The bore of the internal barrel is closed by the end covers carrying the exhaust valves. These end covers are slightly checked down to fix their position, and where they fit within the bell-mouth are screw threaded. The thread is filled with graphite and oil paste, and insures a good steam-tight joint. Butting against the check on the end cover, the flange on the internal barrel and the flange on the external barrel is, at each end, the flange of an approximately rectangular box. These boxes (see Fig. 1) are provided with removable top covers, and on their lower surfaces are formed with a depending rectangular exhaust steam branch. These branches are, as shown in Fig. 6, united by a square sectioned pipe lying beneath the cylinder, and having a central exhaust pipe leading to the atmosphere or the condenser.

Next, as to the valves and the mechanism by which they are driven. As will be seen from Fig. 1, the end covers of the cylinders carry at their center a projecting sleeve. This sleeve extends right across the rectangular exhaust box, and has its open end made tight in the wall. At the crank end of the cylinder, that is, the end shown in Fig. 1, the piston-rod passes through this sleeve, and is here surrounded by the packing represented in Fig. 3. On the external surface of each sleeve is a long feather key, which guides a spider (see Fig. 2) provided with six arms for the reception of the exhaust valve spindles. The spider is of phosphor bronze, and is made in two parts, which are bolted together round the sleeve on the end cover. The valves are also of phosphor bronze, and each is provided with three guiding fins close up against the head (see Fig. 2). All six exhaust valves open and close simultaneously. The reciprocation of the spider for this purpose is effected by means of a shaft passing across the exhaust box and provided with two depending arms, which engage between lugs cast on the sides of the spider (see Fig. 9). The shaft is supported at one end in a blind boss on the side of the exhaust box. At the other it passes through a gland in the wall of the box, and is carried in a bracket *A* (Fig. 9), bolted to the external surface. A lever *B* is here secured to the shaft. One arm of this lever is pulled upon by a spring attached at *C*, the action

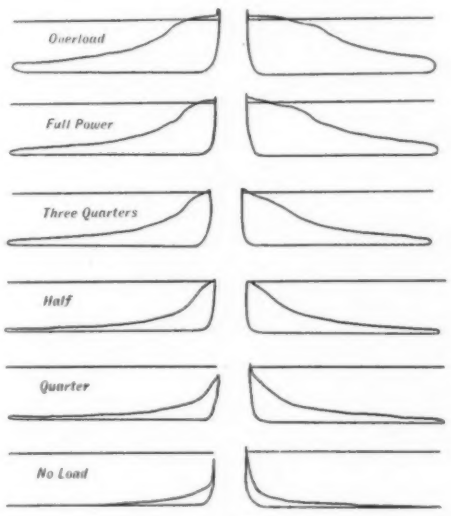


Fig. 8.—Indicator diagrams—low-pressure engine.

of which is constantly tending to close the exhaust valves. The other arm of the lever is formed with a flat bearing surface *D*. Lower down the bracket *A* carries a short spindle *E*, to which is attached the crank lever *F*. The crank on this lever is coupled up by the rod *G* to an eccentric on the engine crank shaft. It is also coupled up by the rod *H* to the similar mechanism operating the exhaust valves at the other end of the cylinder. On the shaft *E* there is further attached a cam block *J*, which, striking against the surface *D*, communicates the motion of the eccentric to the exhaust valves, and opens them at the required instant. The time of opening may be adjusted over a certain range by means of the set screw *K* carried by the lever *F*. This mechanism gives a very quick opening and closing to the valves, and is not by any means as noisy as one might expect it to be from its description.

The admission valves are driven in a very similar manner. Instead of a simple eccentric they are operated by what is practically a shaft governor arranged within the fly-wheel whereby the travel of the admission valves is automatically controlled. From the governor a rod passes to a rocker arm journaled on the side of the main bed plate; this rocker arm, as will be seen from Fig. 6, is duplicated on the other side in connection with the exhaust valve gear. From the rocker arm a rod *A* (Fig. 10) passes back to a gear very similar to that shown in Fig. 9. The cross shaft *B*, however, does not go through the exhaust box; it is disposed outside it, as shown at *B* (Fig. 1). On each side of the engine center line two arms *C* (Fig. 10) depend from the shaft *B*, and embrace between them the head *D* of a valve rod. The two valve rods slide in bosses formed on the sides of the exhaust box (see *L*, Fig. 9), and passing into the interior of the steam jacket are connected at *M M* (Fig. 5) to the ring surrounding the group of admission valves. Since the shaft *B* (Fig. 10) is driven from one end only it is necessary, in order to avoid twisting the admission valve ring, to provide some means of equalizing the strain due to torsion. To accomplish this the arms *C* are not mounted directly on the shaft, but on sleeves surrounding it. These sleeves extend inward toward the center line of the engine, where they are clamped in a basket *E* (Figs. 1 and 10). The shaft *B* is continuous through both sleeves, and inside the basket carries on a key a short arm *F* (Fig. 1). Set screws *G* in the walls of the basket clamp this arm in place. In this manner the two pairs of arms *C* (Fig. 10) are disposed symmetrically with reference to the point on the shaft *B*, from which they are operated. It may also be noted that the set screws G (Fig

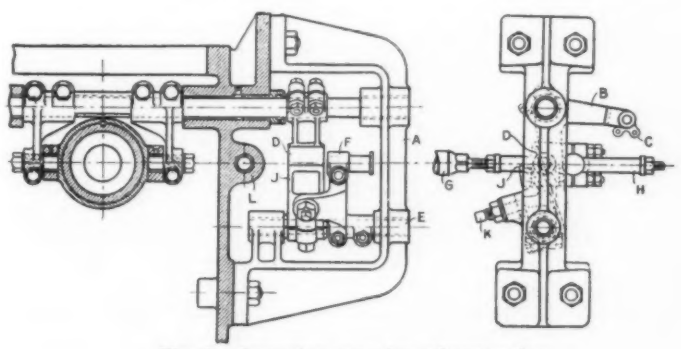


Fig. 9.—Operating gear for exhaust valves.

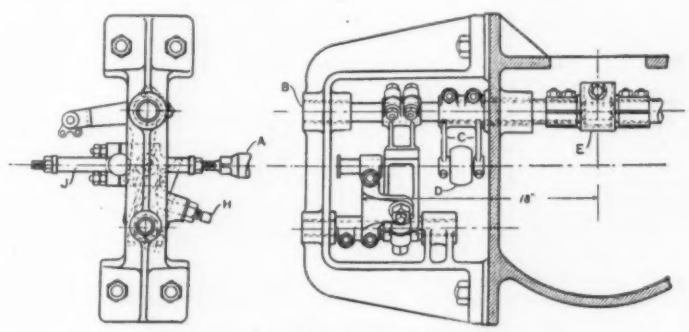


Fig. 10.—Operating gear of admission valves.

1) afford a ready means of altering the lap and lead of the admission valve. The set screw H (Fig. 10) permits of the lead of the valve being altered separately. As in the case of the exhaust valves, the admission valve at the crank end of the cylinder is coupled up, by the rod *J* (Fig. 10), to the admission valve at the other end.

Both the high and the low-pressure engines have recently been tested by Prof. John Goodman, of Leeds University. The tables below, Nos. I and II, present a summary of the results relating to the high-pressure engine, first, when running condensing, and secondly, when running without a condenser. This engine has a cylinder diameter of 16 inches, and a stroke of 18 inches.

We need make very little comment on these figures. In Prof. Goodman's report they are compared with the performances of certain other engines by well-known makers. We refrain from publishing the comparisons *in extenso*, and will summarize the matter thus: Taking the Shuman-Haines engine, running first of all with a condenser, Prof. Goodman compares it with condensing compound engines. The precise feature compared is the steam consumption per indicated horse-power hour. The figures under this head vary from 20.8 pounds downward, the five best results being as follows:

Engine.	H.P.	Steam pressure, lb.	Steam consumption, lb.
A	548	90	13.46
B	247	85	13.35
C	590	160	12.84
D	643	135	12.16
E	305	91	12.19
S-H	96	150	12.4

The last line in this table gives the result obtained with the Shuman-Haines' simple engine as taken from the data of Table I below. It will be seen that it occupies third place in spite of the fact that it is being compared with compound engines of from three to seven times its size.

TABLE I.—*Results of Tests, High-pressure Engine, Condensing. Revolutions per Minute, 200.*

Nominal load	Half.	Full.	Overload.
Length of test	2 hrs.	3 hrs.	2½ hrs.
Barometer, inches of Hg.	29.70	29.63	29.66
Steam pressure, lb., per square inch above atmosphere	147.2	147.0	146.4
Ditto, absolute	161.8	161.6	161.0
Condenser vacuum inches Hg.	28.58	28.45	28.33
Ditto, corrected to 30in. barometer	28.88	28.82	28.67
Steam temperature (observed) Fah.	362	367	363
Exhaust temperature (observed) Fah.	83.3	82.2	90.5
Condensed steam per hour, including jacket steam, lb.	915	1437	2291
Dry steam per B.H.P. hour, lb.	18.2	14.9	16.1
Dry steam per I.H.P. hour, lb.	13.6	12.4	14.1
Dryness fraction of steam	0.98	0.97	0.97
Indicated horse-power	67.2	115.6	162.3
Gross brake horse-power	51.8	97.9	143.8
Power required to drive air and hot-well pumps	1.7	1.7	1.7
Net brake horse-power	50.1	96.2	142.1
Mechanical efficiency per cent.	74.6	83.2	87.6
Efficiency ratio on Rankine cycle on, B.H.P. basis, per cent.	40.5	48.7	47.1

Comparing it in a similar manner with certain compound non-condensing engines, Prof. Goodman quotes the following results:

Engine.	H.P.	Steam pressure, lb.	Steam consumption, lb.
F	150	94	22.0
G	36	130	20.35
H	large	150	19.5
J	39	150	19.45
K	42	157	19.14
S-H	104	150	18.3

The last line again refers to the Shuman-Haines' engine, and is taken from Table II below. It

TABLE II.—*Results of Tests, High-pressure Engine, Non-condensing. Revolutions per Minute, 200.*

Nominal load	Light.	Half.	Full.	Overload.
Length of test	2 hrs.	2 hrs.	3 hrs.	2½ hrs.
Barometer, inches of Hg.	29.74	29.72	29.71	29.74
Steam pressure, lb. per square inch above atmosphere	150.5	145.4	148.2	146.2
Ditto, absolute	165.1	160.0	162.8	160.8
Steam temperature (observed) Fah.	364	365	364	364
Exhaust temperature (observed) Fah.	212	212	212	212
Condensed steam per hour, including jacket steam, lb.	479	1506	2300	3027
Dry steam per B.H.P. hr., lb.	—	27.6	22.1	21.5
Dry steam per I.H.P. hr., lb	—	19.9	18.3	19.0
Dryness fraction of steam	0.98	0.96	0.97	0.98
Indicated horse-power	—	75.6	126.0	159.7
Brake horse-power	—	54.6	104 3	140.6
Mechanical efficiency, per cent.	—	72.2	82.8	88.1
Efficiency ratio on Rankine cycle on B.H.R. basis, per cent.	—	53.0	66.3	68.2

will be seen that it gives the best figures, although it should be noticed that the comparison in three of the instances is made with engines of only one third or so of its power.

The low-pressure engine has a cylinder diameter of 36 inches and a stroke of 36 inches. The whole success of this engine depends, of course, on the availability and maintenance of a high vacuum. For this purpose the inventors have produced special air and hot-well pumps. At present we are not at liberty to describe these, but we may say that they are said to be highly efficient in spite of their simple design. The following table gives the results of Prof. Goodman's tests on the low-pressure engine. It should be remarked that the power required to drive the circulating pumps is omitted from both Table I and Table III.

TABLE III.—*Results of Tests on Low-pressure Engine. Speed, 127 Revolutions per Minute.*

Nominal load	A.	B.	C.	D.	E.	F.
Length of test	1 hr.	1 hr.	2 hrs.	1½ hrs.	3 hrs.	2 hrs.
Barometer, inches Hg.	30.12	29.98	29.94	29.95	29.95	30.12
Steam pressure, inches Hg. above atmosphere	2.03	2.03	1.63	2.03	2.03	2.03
Ditto, lb. per square inch, absolute	15.80	15.73	15.51	15.72	15.72	15.80
Condenser vacuum, inches Hg.	28.85	28.79	28.61	28.65	28.66	28.65
Ditto, corrected to 30in. barometer	28.73	28.81	28.67	28.70	28.71	28.53
Steam temperature (observed) Fah.	215	215	214	215	215	215
Exhaust temperature (observed) Fah.	85.3	83.3	85.3	87.2	87	91.7
Condensed steam per hour, including jacket steam, lb.	470	920	1595	2097	2768	3482
Steam per B.H.P. hour, lb.	—	30.4	26.0	23.1	22.4	23.5
Steam per I.H.P. hour, lb.	22.7	18.2	19.6	18.8	19.6	20.9
Gross brake horse-power	—	32.1	63.9	93.0	125.8	150.3
Horse-power required to drive air and hotwell pumps	1.8	1.8	2.5	2.2	2.4	2.1
Net brake horse-power	—	30.3	61.4	90.8	123.4	148.2
Indicated horse-power	21.3	50.6	81.4	111.3	141.5	166.7
Mechanical efficiency per cent.	—	59.9	75.4	81.6	87.2	88.9
Efficiency ratio per cent. on Rankine cycle on B.H.P. basis	—	42	49.4	56.1	57.7	57.3

A = Light. B = Quarter. C = Half. D = Three-quarters. E = Full. F = Overload.

The following is a quotation from Prof. Goodman's report on the trials of the low-pressure engine:

"A comparison between the steam consumption per brake horse-power of this engine and an exhaust steam turbine is of interest. There appears to be very little published data upon the steam consumption of exhaust steam turbines of moderate power. Morrow, in his recent book on 'Steam Turbine Design,' gives a diagram on page 188 showing the steam 'consumptions at full load of exhaust steam turbines of various sizes,' per kilowatt-hour. Reducing his figures to consumptions per horse-power hour we get:

Horse-power.	Steam per horse-power hour, lb.
100	31.5
150	29.0
200	27.7
500	25.5
1000	24.7

"A test by Rateau on an exhaust team turbine of 700 horse-power gave 29.7 pounds per horse-power hour. Other tests by Rateau (I.M.E., 1904) on a 300 horse-power turbine gave 39.5 pounds per horse-power hour with an initial pressure of 14.7 pounds square inch, and a condenser pressure of 2.79 pounds square inch. The conditions are not quite the same as in the tests of the engine now under consideration, but the 22.4 pounds of steam per brake horse-power hour obtained on the Shuman-Haines' engine compares very favorably with the values given above.

"A simple statement of the relative steam consumptions per horse-power hour of two engines is not always a fair comparison unless the initial steam pressure and the vacuum be the same in both cases. A rigid comparison can be made by comparing the steam required for a perfect steam engine working on the ideal Rankine cycle under the same initial and terminal conditions with the actual consumption of steam the ratio is known as the efficiency ratio of the engine. In calculating this quantity the jacket steam has been reckoned on the same basis as the cylinder steam, but if the jacket water were drained back direct to the boiler the jacket steam should only be credited with latent heat. If this were done in the present instance it would raise the efficiency ratios from ½ to 1 per cent, but it is not usual to make this assumption."

In Fig. 9 we reproduce some indicator diagrams taken on the high-pressure engine when running condensing and when running non-condensing, and in Fig. 8 indicator diagrams taken on the low-pressure engine are given. On page 29 will be found some general views of the two types.

The Origin of Worlds

(*Concluded from page 21*)

The preceding paragraphs have developed a cosmogonic theory, which is entirely different, and the probable superiority of which is due to the circumstance that more than any other, it is based on experimental analogy.

I have supposed all space to be filled with corpuscles of every kind, and I have pictured celestial bodies as perpetual, alternating in action with the flying atoms of space. This agrees well with the facts revealed by the spectroscope in its most improved form. It has been found, as every one knows, that the stars that lie farthest from us in space are formed of the same matter as the sun and our earth. Besides, measurements and calculations of binary stars teach us that no matter how far our telescopes penetrate into space, all movement is subservient to the same laws of gravitation.

This conception of the genesis of celestial bodies by flying atoms is also found in the idea of "Panspermia"—that all life on celestial bodies spring from embryos that came from infinite space. It would follow, as in the case of matter, that all living beings in the universe are probably related to one another.

In conclusion let us examine humanity in the light of the history of evolution.

The harmonious results of different investigations seem to indicate that the earth has existed as a globe for about a billion years. Man appeared and developed during a small fraction of this period. But if we consider his present development, we are filled with astonishment. It cannot be denied, indeed, that in the course of the last two centuries mankind has developed, from the standpoint of culture and of science, far more rapidly than in the previous hundreds of thousand of years.

How long a time is still allotted to man? The history of geology teaches us that life on the earth is not a short episode. Henri Poincaré has said that "thought is only a flash in a long night," and he thus referred to the obscurity which enveloped the earth and which will envelop it again when all human handiwork will perish.

From what has been said it would seem to follow that new worlds will be born in space with greater frequency than human beings are born on this earth. It is, therefore, easy to believe that each world has its "flash in a long night," accompanied by the struggle of reasoning creatures, with all their thoughts and all their discoveries, a flash which will disappear without leaving any trace; and that worlds will die more frequently than living beings die on the earth, or more exactly, that they will die in unlimited numbers.

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Table of Contents

	PAGE
Radiation Pressure.—By Prof. Wilson C. Morris	18
Sudden Blanching of the Hair	19
The Origin of Worlds.—II.—By Prof. Kristian Birkeland.—6 illustrations	20
The Production of Caustic Alkali and Bleach.—By D. J. Allmand.—2 illustrations	22
Regulation of the Heat of the Body in Hot Climates	23
The Development and Status of the Wood Preserving Industry.—By E. A. Sterling.—9 illustrations	24
The Liquid Air Industry	27
Radio-active Manures	27
Charles Proteus Steinmetz.—By Douglas Southerland Martin.—1 illustration	28
The Shuman-Haines Steam Engine.—14 illustrations	29